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PEDESTRIAN SAFETY PROJECT

NATO Committee on the Challenges of Modern Society

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National Highway Traffic Safety Administration

March 1974

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PEDESTRIAN SAFETY PROJECT

COMMITTEE ON THE CHALLENGES OF MODERN SOCIETY
CCMS REPORT NO.27

SÉCURITÉ DES PIÉTONS

COMITÉ SUR LES DÉFIS DE LA SOCIÉTÉ MODERNE
RAPPORT N°27 du CDSM

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PRICES SUBJECT TO CHANGE

PREFACE

ORIGINS OF CCMS AND THE ROAD SAFETY PILOT STUDY

On April 10, 1969 – less than four months after taking office – President Nixon called for NATO to take action on environmental problems, declaring

“... (NATO) needs a social dimension, to deal with our concern for the quality of life in this final third of the twentieth century ... the industrial nations share no challenge more urgent than that of bringing 20th century man and his environment to terms with one another ...”

In November 1969, NATO accepted the President's proposal, established the Committee on the Challenges of Modern Society – CCMS – and directed it to improve in every practical way the exchange of views and experiences among the allied countries in the task of creating a better environment for their societies, and to consider specific problems with the deliberate objective of stimulating action by member governments.

To carry out its mandate, CCMS developed a novel approach under which one NATO member as “Pilot” assumes responsibility for undertaking and completing a program. With one-nation leadership, programs move ahead quicker than under the working committee approach which is characteristic of most international efforts. Also, the need for an international secretariat is substantially reduced.

At the first CCMS meeting in the late fall of 1969, the U.S. Representative to CCMS proposed a program on all aspects of road safety – vehicle, highway, driver – as a CCMS effort which the U.S. would lead. NATO accepted. The Department of Transportation's National Highway Traffic Safety Administration conducted the Study for the United States.

The Road Safety Pilot Study was divided into seven projects, each led by a NATO ally: Pedestrian Safety – Belgium; Alcohol and Highway Safety – Canada; Motor Vehicle Inspection – Federal Republic of Germany; Road Hazards Identification and Correction – France; Emergency Medical Services – Italy; Accident Investigation – Netherlands; and Experimental Safety Vehicle – United States. Each of these efforts was a self-contained project in its own right and apart from

overall coordination by the U.S. as Pilot Country has been directed by the NATO country indicated. The other allies have participated in those projects of major interest to them and such participation is noted in the final report for each of the seven projects. The conclusions and recommendations contained in these project reports are, in turn, discussed in the overall Pilot Study report.

The basic purpose of CCMS is to stimulate government action – not research per se. While more research is needed in all aspects of road safety, the CCMS premise is that much is already known in one country which other countries might utilize or adopt to their unique problems. Thus, an overriding goal of all of the road safety projects has been to organize the extant knowledge on road safety programs of proven effectiveness in a manner that will facilitate putting these programs into practice where they are not now in operation.

THE PEDESTRIAN SAFETY PROJECT

This is the final report of the Pedestrian Safety Project which has as its aim the examination of the problem and current activities in order to recommend corrective action for member countries.

The need to include pedestrian safety in a road safety project is both obvious and urgent. Pedestrians are a significant part of the problem, accounting for 12% to 34% of the road accident victims in the countries participating in the project.

Tragically, it is the young and the old who bear the brunt of these accidents with both groups being over-represented in pedestrian fatalities. More tragically, their deaths and injuries pass relatively unseen, unheard, and with a lack of public and official concern bordering on tacit acceptance.

Pedestrians speak with no strong voice, as do other road users. They are not consumers of an industry devoted to servicing their road user needs. And, typically, they are beyond the focus of road safety efforts which tend to emphasize the road, the vehicle, and the driver or passenger. Despite their theoretical status as co-equal users of the road system, they continue to be injured and to die in a general atmosphere of invisibility. In the future, when

improvements in car-occupant safety features have yielded their anticipated benefits, the pedestrian problem will loom even larger by comparison. It is a problem whose first step toward solution is the recognition that a problem does exist.

PROJECT HISTORY

In response to a request from the United States, Belgium, represented by Mr. J. Vrebos, Secretary General of the Ministry of Communications, accepted the responsibility for the Pedestrian Safety Project of the Pilot Study. A group of experts was formed and held its initial meeting in Brussels in September 1971. Current activities in member countries were discussed and a project approach plan was developed. It was decided to:

1. Conduct a survey of the current situation in member countries by mail questionnaire.
2. Divide the problem into a number of subject areas, each of which would be assigned to a member country who would take responsibility for (a) suggesting items for the questionnaire, (b) analyzing questionnaire responses, and (c) preparing recommendations for action based on their own knowledge and expertise.
3. The areas of activity selected were as follows:
 - Statistics
 - Psychology (Human Factors)
 - Micro-Environment
 - Urban Planning
 - Vehicle
 - Detection of Abnormal Risk

A second meeting was held in Copenhagen in June 1972, where available questionnaire responses and expert papers were reviewed. A draft recommendation regarding pedestrian/vehicle safety was prepared. Analysis of the state of knowledge and activity in member countries led to the identification of two needs that would have to be fulfilled in order for member countries to implement effective pedestrian safety programs: (1) research and evaluation to determine effective actions, and (2) the involvement and awareness of various levels of government officials.

In order to provide actual experience with the U.S. situation and experimental measures, a meeting in Washington, D.C. and Miami, Florida was arranged in April 1973. Delegates from the Pedestrian Safety Group of the OECD were invited to participate in this meeting.

A third meeting took place in London in June 1973, at which time the expert reports were reviewed

and final recommendations were drafted. These recommendations, which are presented in Part One of this report, call for a set of activities which should be pursued by member governments and which would benefit from cooperation among them.

ORGANIZATION AND REPORT

The report of the Pedestrian Safety Project is divided into two parts. The first part presents conclusions and recommendations that resulted from the project activity. Eight areas are treated: (1) allocation of resources, (2) pedestrian crossing systems - regulation and enforcement, (3) traffic management and urban transportation planning, (4) education and information, (5) urban planning, (6) vehicle driver, (7) pedestrian behavior, and (8) statistics. In each case, a general conclusion reached by the group, based on the papers and other evidence of discussion, is given first. This is accompanied by an action recommendation that follows directly from the conclusion and is aimed at improving the specific situation. An attempt has been made to keep the conclusions and recommendations short and to include only their essential features.

The second part contains papers prepared by the participants, which were reviewed and discussed by the group. Comments were given to the authors and in some cases the original papers were modified. There was general acceptance of the contributions by the individual experts. These papers were a primary source for the findings and conclusions of the group.

ACKNOWLEDGMENTS

Dr. J. P. DeCoster, Director of Fonds d'Etudes et de Recherches sur la Securite Routiere served as project leader. He assembled a group of experts including government representatives and organizations dealing with pedestrian safety. Those who participated are as follows:

Belgium	
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In addition, the following knowledgeable observers
attended one or more meetings and provided valuable

help to the group:**Denmark**

N. O. Jorgensen

Danish Council of Road
Safety Research

Sweden

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J. Older

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Finally, Dr. Alfred J. Farina, NHTSA, United States,
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activities at that time.

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PART ONE

CONCLUSIONS AND RECOMMENDATIONS

PART ONE

Conclusions and Recommendations

ALLOCATION OF RESOURCES

CONCLUSIONS

Pedestrian injuries and fatalities are a very sizable proportion (20 to 40%) of the road safety problem. In many countries they account for almost half of the problem, but receive a very small percentage of the road safety effort and budget.

RECOMMENDATIONS

- Member countries should review their allocations for road safety both in research and current measures, with a view towards allocating this effort more in proportion to the extent of the problem contributed by pedestrian casualties.

PEDESTRIAN CROSSING SYSTEMS REGULATION AND ENFORCEMENT

CONCLUSIONS

There exists a great variety of pedestrian crossing systems with or without traffic lights. Little is known about their safety effectiveness. There are also differences in the national regulations and in the levels of enforcement of the regulations, if any, applied to pedestrians.

RECOMMENDATIONS

- To realize comparative evaluation programs of existing or newly developed systems and rules to assure safe crossings for pedestrians.
- To realize uniform adoption of the best systems and appropriate regulations.
- To assure a good enforcement of these regulations.

TRAFFIC MANAGEMENT AND URBAN TRANSPORTATION PLANNING

CONCLUSIONS

A significant effort is given to traffic management and urban transportation planning with the objective of moving vehicular traffic more swiftly, but little attention is given to the safety of pedestrians.

RECOMMENDATIONS

- Governments should take action to ensure that, as traffic management and urban transportation planning schemes are considered for application in specific situations, more provision should be made to improve pedestrian safety. Governments should at the same time investigate the use of traffic management techniques specifically for dealing with pedestrian safety problems.

EDUCATION AND INFORMATION

CONCLUSIONS

Pedestrian safety is given a relatively low priority by both the public at large and officials at the central and local level. A need exists to inform them and stimulate action.

In addition there is insufficient information about the value of existing educational programs. Doubt has been cast on the value of the present form and use of traffic gardens. However, some existing or newly developed education or information programs may be effective. There is need for more comparative evaluation.

RECOMMENDATIONS

- Educational programs should include a specific effort to ensure that people working in the public service in related fields such as planning, engineering and teaching should be aware of the nature and gravity of the pedestrian safety problem so that they are more alert to the implications for pedestrian safety of their own work.
- Governments should develop and evaluate programs of publicity training and education. At the same time research should be carried out into the comparative value of different techniques. Training programs for children should be conducted using situations that will produce the appropriate responses in real life traffic. Publicity programs for other age groups should be as specific as possible both as to the target audience (old people, drivers, etc.) and as to the behavior advocated.

VEHICLE DESIGN

CONCLUSIONS

There has been relatively little effort directed at the protection of pedestrians through vehicle design.

Vehicle design has been directed mainly at the prevention of injury to vehicle occupants and the reduction of property damage. Vehicle design for pedestrian protection should be given equal priority with occupant protection and higher priority than property damage.

RECOMMENDATIONS

- The problem of pedestrian injury mitigation through improved vehicle design should accordingly be considered by governments through biomechanics and vehicle structures research and development programs.
- National ESV specifications should include pedestrian protection. In principle sound applicable injury tolerance criteria should be applied to the pedestrian in impacts up to 20 mph.
- Once developed and validated, vehicle design changes resulting from applied research programs and ESV programs should be incorporated in motor vehicle design requirements as soon as possible.

URBAN PLANNING

CONCLUSIONS

There is insufficient appreciation on the part of most planners of the need to plan for pedestrian safety. The difficulty stems largely from the lack of any adequate data telling planners what forms of layout will produce what numbers and types of accidents.

The Group draws attention to the pioneering work of the Planfor in Sweden in developing a technique for measuring risk to pedestrians through observation of behavior.

RECOMMENDATIONS

- The Group recommends urgent study of this technique by member countries with a view to its evaluation as quickly as possible in view of its high potential value as a planning tool.
- If and when this technique has been validated by member countries they should organize centrally the collection of behavioral data relating to the incidence of
 - safe
 - dangerous and
 - emergency evasive action by pedestrians in those combinations of
 - traffic environment (physical configuration, traffic volumes, etc.) and
 - traffic situations (vehicle movements, etc.) which are associated with high numbers of accidents.
- They should identify those traffic environments with high numbers of accidents and analyze some of them particularly in respect of the location of possible immediate destinations for the pedestrian traffic.
- They should centrally organize records, on accident report forms, of the immediate destinations of pedestrians involved in accidents.
- They should develop principles and criteria based on the work carried out in pursuance of 1, 2, 3 and 4 paragraphs above.
- Local planning should, as regards road safety considerations, be based on risk values as expressed in the country's recommended principles and criteria.
- International exchanges of data should be organized after they had been collected centrally in the country.

PEDESTRIAN BEHAVIOR

CONCLUSIONS

In the field of pedestrian behavior only a limited set of variables has been investigated and available results are not always applied in countermeasures.

Many personal variables such as motives (e.g. for route-choosing) and attitudes towards other pedestrians, drivers and their environment are not known yet.

RECOMMENDATIONS

- More attention should be given to improve knowledge of the relationship between pedestrians and motorists.
- The governments should take steps to apply the results from already known investigation into countermeasures.
- More studies should be done in the field of the personal variables of the pedestrians in relation to other pedestrians, motorists and the pedestrian environment.

STATISTICS

CONCLUSIONS

Many data and crossings of data are missing for obtaining an accurate understanding of pedestrian accidents.

RECOMMENDATIONS

- Governments should develop agreed sets of data that will increase the comprehension of the causes and consequences of pedestrian accidents.
- Governments should carry out pedestrian and drivers behavior studies as one approach to increased pedestrian safety planning.

PART TWO

STATISTICS

Answers To The Questionnaire

The Use Of Statistics

Recommendations

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Answers To The Questionnaire

The figures refer to the year 1970 for Sweden, The Netherlands, Japan, Italy, Denmark, Belgium, United Kingdom, Federal Republic of Germany, Turkey, Canada; to 1971 for the United States and to 1967 for France.

The data for Belgium, France and Italy cannot be compared fully with those of the other countries as the definition they use for killed, seriously injured and slightly injured differ from the E.C.E. definition used there.

BELGIUM:

- killed: a victim who dies at the scene of the accident
- seriously injured, slightly injured: definition of E.C.E.

FRANCE:

- killed: a victim who dies within 6 days of the accident
- seriously injured: a victim who stays in the hospital for more than 6 days.

ITALY:

- killed: a victim who dies within 7 days of the accident.

The fatality figures for the United States have been corrected to show deaths occurring within 30 days of the accident as opposed to the customary U.S. criterion of one year. Because of the possible inaccuracy of the correction to "30 day deaths" and the fact that basic reports are not available from some States, the figures have to be considered as estimates.

Legend

B	Belgium
C	Canada
D	Denmark
F	France
G	Germany
NL	Netherlands
S	Sweden
T	Turkey
UK	United Kingdom
US	U.S.A.

Number of fatalities for each category

Number of fatalities for all categories

Severity rate = $\frac{\text{Number of fatalities for each category}}{\text{Number of fatalities for all categories}}$

Number of victims for each category

Number of victims for all categories

**PERCENTAGE OF VICTIMS OF ROAD ACCIDENTS
FOR EACH CATEGORY OF ROAD USERS**

Category of road users	B	C	D	F	G	I	J	NL	S	T	UK	US
Bicycles	12.13	2.74	12.07	5.03	7.66	5.75	9.04	12.72	8.30	1.41	6.36	
Cycles w. aux. engine	8.30		14.26	29.29	3.71	13.38	6.21	36.49	8.09		1.26	
Motorcycles	2.01	4.10	5.56	1.92	5.10	12.14	13.44	3.09	4.96	4.72	12.38	
— driver	29.51	40.44	54.15	52.80	34.72	24.70	51.96	17.96	32.99	5.01	22.32	
— passenger	20.30	40.77	54.15		29.03	23.11		15.07	29.84	13.92	22.41	
Coaches and buses	0.71			0.58	0.91	1.51		2.50	3.03	16.32	4.38	
Tramways/trolleybuses			0.16		0.20	0.24						
Other motor vehicles	3.63			2.82	3.25	2.61	0.95		0.63	23.32	7.38	
Pedestrians	23.41	11.61	13.81	13.47	15.16	16.54	18.27	11.45	11.99	34.20	23.49	

SEVERITY RATE OF ACCIDENT FOR EACH CATEGORY OF ROAD USERS

Category of road users	B	C	D	F	G	I	J	NL	S	T	UK	US
Bicycles	1.17	0.93	1.16	1.23	1.24	1.90	1.18	1.33	1.30	0.45	0.78	
Cycles w. aux. engine	0.61		0.89	0.79	0.98	0.81	1.51	0.50	1.02		0.62	
Motorcycles	0.94	0.95	0.60	0.70	0.87	0.80	0.65	0.89	0.82	0.49	0.76	
— driver	0.97	0.95	0.78	1.02	0.79	0.87	0.39	1.21	0.85	0.64	0.95	
— passenger	0.72	0.73		0.80	0.67	0.70		1.14	0.68	0.59	0.76	
Coaches and buses	0.66			0.09	0.14	0.03				0.79	0.23	
Tramways/trolleybuses			0.50		0.20	0.03			0.86			
Other motor vehicles	0.97			1.26	1.04			1.12	2.56	1.28	0.88	
Pedestrians	2.31	2.14	2.00	1.71	2.08	1.57	1.94	1.71	1.97	1.23	1.66	
Others		2.09		1.50	1.83	0.43	1.97	1.26	3.81	0.71		

**NUMBER OF PEDESTRIAN VICTIMS
(PER 100,000 INHABITANTS) FOR EACH AGE GROUP**

Age	B	C	D	F	G	I	J	NL	S	T	UK	US
0 - 5	127		113.9	<u>65.65</u>	183.0	5.66	414.2	119.7	<u>44.18</u>	15.5	239	
6 - 9	244		205.2	<u>159.23</u>			396.8	166.4		33.3	441	
10 - 14	123		79.9	<u>72.66</u>	299.3	13.97	89.9	57.7	<u>47.77</u>	25.9	277	
15 - 17			61.0		130.1	4.43	76.4	45.2	36.46	17.9	196	
18 - 20	98		52.9	<u>72.22</u>	119.2			37.0	<u>31.35</u>	14.0	167	
21 - 24			32.5	<u>62.34</u>	83.4	4.73	109.0	27.7	<u>24.77</u>	15.4	96	
25 - 64	74		44.5	<u>69.19</u>		10.93	115.5	31.3	24.80	14.8	86	
65 and over	162		152.2	160.13	174.3	10.87	190.7	99.5	60.72	36.8	167	

NOTE: Numbers underlined indicate not exactly the same limits of classes

**NUMBER OF PEDESTRIANS KILLED
(PER 100,000 INHABITANTS) FOR EACH AGE GROUP**

Age	B	C	D	F	G	I	J	NL	S	T	UK	US
0 - 5	3.7	<u>6.92</u>	0.7	<u>3.91</u>	9.4	0.31	9.40	8.7	<u>4.01</u>	3.9	5	<u>4.92</u>
6 - 9	4.1	<u>13.82</u>	11.3	<u>9.08</u>	9.0	0.49	5.02	6.8	<u>3.18</u>	7.8	7	<u>9.48</u>
10 - 14	1.7	<u>6.23</u>	3.8	<u>2.67</u>			0.91	2.4		5.7	3	<u>2.80</u>
15 - 17			3.1	<u>3.02</u>	4.8	0.07	0.92	2.0	3.08	3.1	4	<u>4.08</u>
18 - 20	1.7	<u>6.24</u>	5.7		5.1			2.2	<u>3.09</u>	2.0	4	
21 - 24			0.6	<u>2.51</u>		0.16	<u>1.46</u>	1.2	<u>1.37</u>	2.1	2	<u>2.10</u>
25 - 64	2.9	<u>6.89</u>	5.2	<u>4.18</u>	6.0	1.53	<u>4.59</u>	2.2	2.13	3.2	3	<u>3.74</u>
65 and over	9.7	12.77	24.0	21.24	31.5	1.77	17.48	18.6	12.13	12	18	11.05

NOTE: Numbers underlined indicate not exactly the same limits of classes

**PERCENTAGE OF PEDESTRIANS KILLED IN
FUNCTION OF THE TYPE OF VEHICLE INVOLVED**

Vehicles	B	C	D	F	G	I	J	NL	S	T	UK	US
Bicycles	0.28	0.19	0.81			0.23		0.87		0.19		
Cycles w. aux. engine		<u>1.30</u>	1.83			2.79		6.15				0
Motorcycles			1.82			5.50		1.48		2.70		0.44
Cars	81.07	83.89	80.67			77.25		67.24		26.27		79.09
Coaches and buses	3.95	10.74	1.83			1.98		1.82		22.38		1.17
Tramways	2.28					0.41		2.62				0
Other motor vehicles	12.43	3.89	33.54			11.84		20.00		47.81		5.01
			lorries									

**SEVERITY RATE OF PEDESTRIAN ACCIDENTS
IN FUNCTION OF THE TYPE OF VEHICLE INVOLVED**

Vehicles	B	C	D	F	G	I	J	NL	S	T	UK	US
Bicycles	0.07					0.21						
Cycles w. aux. engine						0.38				1.13		
Motorcycles and scooters						0.60				0.88		
Private cars	1.08					1.03				1.85		
Coaches and buses	2.21					1.51				1.14		
Tramways/trolleybuses	1.37					0.93				1.12		
Other motor vehicles	1.71					2.39						

PERCENTAGE OF PEDESTRIANS KILLED IN FUNCTION OF THE HOURS

Hours	B	c	D	F	G	I	J	NL	S	T	UK	US
0 - 1	2.22	7.04	0.91					2.82		2.86		
1 - 2	3.32		0.91					1.56		1.50		
2 - 3	3.32	3.82	1.22					0.89		1.74		7.78
3 - 4	2.22	0.74	0.30					0.11		1.92		
4 - 5	0.83	0.19						0.22		2.04		
5 - 6		0.19	0.30					0.28		2.16		4.72
6 - 7	0.55	0.55	2.44					0.56		4.20		
7 - 8	0.83	0.74	2.44					2.12		4.96		
8 - 9	3.05	1.85	2.74					2.95		4.80		6.40
9 - 10	3.05	2.78	3.35					3.51		5.78		
10 - 11	2.22		5.46					3.96		5.16		
11 - 12	3.32	2.78	2.44					5.74		5.28		9.02
12 - 13	3.80	2.96	3.96					4.74		4.80		
13 - 14	1.94	2.96	3.35					6.07		5.40		
14 - 15	2.77	3.33	5.79					5.35		7.92		13.33
15 - 16	3.32	4.07	6.46					6.57		7.66		
16 - 17	4.78	7.59	11.59					10.47		6.90		
17 - 18	7.78	6.52	11.59					11.48		6.54		22.46
18 - 19	12.47	8.15	10.37					9.42		4.86		
19 - 20	11.38	7.59	8.23					7.58		3.54		
20 - 21	10.53	10.00	4.27					4.90		2.94		22.14
21 - 22	5.26	7.41	5.18					3.29		2.22		
22 - 23	7.20	4.63	4.27					2.95		3.12		
23 - 24	3.32	5.19	2.44					2.67		1.86		14.17
unknown	0.43	7.04								0.84		
±22 - 1												

SEVERITY RATE OF PEDESTRIAN ACCIDENTS IN FUNCTION OF THE HOURS

Hours	B	C	D	F	G	I	J	NL	S	T	UK	US
0 - 1	1.90									1.16	1.46	
1 - 2	3.53									1.67	1.36	
2 - 3	4.74									1.96	1.58	
3 - 4	5.69									2.40	1.43	
4 - 5	3.61									2.29	1.00	
5 - 6										1.66	1.18	
6 - 7	0.72									1.50	1.23	
7 - 8	0.24									1.00	1.09	
8 - 9	0.67									0.87	0.83	
9 - 10	1.09									0.98	0.89	
10 - 11	0.61									0.81	1.00	
11 - 12	0.63									0.81	0.96	
12 - 13	0.63									0.89	0.96	
13 - 14	0.39									0.83	0.86	
14 - 15	0.56									1.07	0.95	
15 - 16	0.56									0.98	0.94	
16 - 17	0.52									0.94	0.89	
17 - 18	0.67									0.95	0.96	
18 - 19	1.07									0.93	1.66	
19 - 20	1.43									0.84	1.11	
20 - 21	1.78									0.92	1.15	
21 - 22	1.81									0.93	1.28	
22 - 23	2.80									1.24	1.35	
23 - 24	1.72									0.93	1.36	

PERCENTAGES OF PEDESTRIANS KILLED IN FUNCTION OF THE DAYS OF THE WEEK

Days	B	C	D	F	G	I	J	NL	S	T	UK	US
Monday	14.13	9.26	14.29				13.86	14.26		13.92	12.38	
Tuesday	14.13	14.07	13.07				11.44	13.20		13.38	13.37	
Wednesday	9.70	13.33	13.96				13.17	14.43		14.40	13.13	
Thursday	11.08	16.48	14.89				12.07	14.42		14.22	14.63	
Friday	16.34	17.78	20.36				13.12	16.16		14.28	16.62	
Saturday	16.34	17.78	13.07				19.78	13.87		14.82	18.94	
Sunday	18.28	11.30	10.33				16.58	13.76		15.00	10.94	

SEVERITY RATE OF PEDESTRIAN ACCIDENTS IN FUNCTION OF THE DAY

Week	B	C	D	F	G	I	J	NL	S	T	UK	US
Monday	0.99		0.91				1.00			0.91		
Tuesday	1.04		0.89				0.89			0.94		
Wednesday	0.87		0.93				0.98			1.05	0.98	
Thursday	0.82		0.96				0.98			1.00		
Friday	1.01		1.12				0.98			1.08	0.98	
Saturday	1.11		1.03				1.20			1.07	1.04	
Sunday	1.39		1.28				0.98			0.99	1.09	

PERCENTAGES OF PEDESTRIANS KILLED IN FUNCTION OF THE MONTHS

Months	B	C	D	F	G	I	J	NL	S	T	UK	US
January	9.42	8.37	9.45		7.41	8.90		7.89		5.20	8.91	8.71
February	8.59	8.74	8.18		7.27	8.19		8.74		5.40	7.85	7.10
March	7.78	8.15	8.40		6.87	8.22		7.82		5.28	7.41	7.47
April	6.09	7.41	3.96		6.34	7.73		8.19		6.18	6.73	7.18
May	9.70	7.89	7.01		7.35	7.47		7.91		8.10	6.89	7.87
June	6.09	9.44	5.49		6.03	8.00		7.88		9.72	6.32	7.30
July	6.09	10.00	7.32		6.75	6.71		7.89		11.22	7.62	7.85
August	6.37	8.89	9.78		7.18	7.81		7.63		12.00	7.27	8.16
September	6.37	7.22	7.62		8.50	8.19		8.41		10.88	8.03	7.99
October	8.86	11.48	11.28		11.41	10.30		10.70		10.80	9.70	9.43
November	13.85	9.44	10.98		12.68	10.18		10.75		8.70	11.82	9.09
December	10.80	9.26	15.55		12.50	10.30		9.19		6.94	11.85	11.86

SEVERITY RATE OF PEDESTRIAN ACCIDENTS IN FUNCTION OF THE MONTHS

Months	B	C	D	F	G	I	J	NL	S	T	UK	US
January	1.15		1.12		1.17	1.07				0.93	1.15	1.05
February	1.04		0.86		0.97	0.98				0.89	1.02	0.85
March	0.96		0.96		0.86	0.99				0.89	0.95	0.90
April	0.79		0.55		0.80	0.93				0.94	0.84	0.86
May	1.14		0.86		0.80	0.90				0.93	0.77	0.94
June	0.73		0.72		0.72	0.72				1.03	0.79	0.88
July	0.86		1.12		0.85	0.81				0.95	0.93	0.94
August	0.85		1.26		1.02	0.94				1.03	0.94	0.96
September	0.76		0.99		1.02	0.98				1.05	0.94	0.96
October	0.94		1.20		1.17	1.24				1.13	1.04	1.13
November	1.40		1.06		1.28	1.22				1.10	1.27	1.09
December	1.26		1.28		1.23	1.24				1.03	1.30	1.42

**PERCENTAGES OF PEDESTRIANS KILLED
IN FUNCTION OF LIGHTING CONDITIONS AND SITE**

Lighting conditions and site	B	C	D	F	G	I	J	NL	S	T	UK	US
Day B (built up area)			63.47					67.15		60.30	85.36	63.74
Day R (rural area)			36.53					32.85		39.70	14.64	36.20
Twilight B			46.67					52.50		52.00		67.84
Twilight R			53.33					47.50		48.00		32.16
Dark with lighting B			84.31					77.06		97.80	94.37	
Dark with lighting R			15.69					22.94		2.20	5.63	.
Dark without lighting B			13.64					10.94		27.41	17.37	
Dark without lighting R			86.36					89.06		72.59	82.68	

*U.S. Dark with and without lighting B : 55.08

R : 44.92

**SEVERITY RATE OF PEDESTRIAN ACCIDENTS
IN FUNCTION OF AGE OF INVOLVED DRIVER**

Age	B	C	D	F	G	I	J	NL	S	T	UK	US
under 18										0.96		
18 - 19										1.04		
20 - 24										0.82		
25 - 29										0.93		
30 - 34										1.04		
35 - 39										1.09		
40 - 44										1.00		
45 - 49										0.98		
50 - 54										0.92		
55 - 59										0.92		
60 - 64										0.95		
65 and over										1.09		

**PERCENTAGE OF PEDESTRIAN VICTIMS IN FUNCTION
OF THE GEOMETRICAL CHARACTERISTICS OF THE PLACE**

Geometrical characteristics of the place	B	C	D	F	G	I	J	NL	S	T	UK	US
Rectilinear		25.07	67.61							82.05	43.20	41.5
Curve			2.79							3.07		
Junction		24.52	17.81							13.14	13.01	19.4
T junction			9.52								34.96	
Y junction			0.63								2.07	
Round about			0.35								1.31	
Other			1.28								4.41	

PERCENTAGE OF PEDESTRIAN VICTIMS IN FUNCTION OF THE TYPE OF ACCIDENT

The type of accident	B	C	D	F	G	I	J	NL	S	T	UK	US
On a pedestrian crossing		0.85	20.79							0.08	8.02	
At a bus stop			1.76									
Crossing a street behind a stationary vehicle		1.37	17.18							6.36	22.32	
Pedestrian coming into sight suddenly on the street		15.16	13.63							57.41		
Crossing in another manner		5.64	32.80								53.67	
Standing on the street			2.96								9.43	
Children playing		6.57	2.96							2.21		
On the footpath		3.67	3.12								6.31	
Walking along the road		8.74	4.71							5.21		
Others		5.97	0.06							28.78		

The Use Of Statistics

The statistics by themselves cannot lead to many recommendations. They can, however, offer the possibility of supporting scientific recommendations concerning the different aspects of pedestrian safety.

In this sense, we can divide this report into four sections:

- definition of the words used and problem of the criteria
- data which must be available
- presentation of the data
- measure of the effectiveness of countermeasures.

DEFINITION OF THE WORDS USED AND PROBLEM OF CRITERIA

In order to compare at an international level the efficiency of different countermeasures in the specific area of pedestrian safety, it is necessary to have comparable data. The first problem met is always the definition of "killed," "seriously injured" and "slightly injured."

There are differences in the criteria used for the definition of these categories of victims. A person killed is a victim who dies

- on the spot
- within 24 hours of the accident
- within 48 hours of the accident
- within 3, 6 or 7 days of the accident
- within 30 days of the accident
- within one year of the accident

Many countries have adopted the definition of the Economic Commission for Europe (E.C.E.). (See Appendix A.) A recommendation could be that all the C.C.M.S. countries adopt the E.C.E. definition.

In the countries where it is not possible to do so, one could recommend that a research project be carried out to establish conversion factors relating their own definition to the international one. These conversion factors would have to be calculated specifically for the pedestrian fatalities, as it appears that the time-to-death curve is different for pedestrians and other motor vehicle users.

The problem of criteria also arises for the seriously and slightly injured. The most commonly used criteria (ECE definition) is that of classifying victims according to the type of injury suffered. This is of course the most objective one.

It appears that the classification of victims as slightly injured according to the definition of ECE depends largely on the national mentalities, time and location of the accident. It seems therefore that this category cannot usefully serve for an international comparison.

One must be sure that nationally-agreed definitions are used throughout each individual country. The application of these definitions must be independent of the interpretation by the person who fills in the accident report form and also of the location and time of accident. Surveys have pointed out that this is not always the case. If data are not homogeneous at the national level it does not make much sense to make an effort at an international comparison.

Of course the standardization of the definitions will not solve all the problems related to international comparisons but it will make it more simple and more meaningful.

DATA WHICH MUST BE AVAILABLE

Data Concerning the Pedestrian Involved

Age and Sex. The pedestrian victims of accidents must be classified in age and sex groups so that target groups can be identified for safety campaigns or other public education actions. This classification could be very useful for the different types of accidents: the information given during safety campaigns will be more meaningful if it is specific for each group and relates directly to the type of accidents in which this group is more frequently involved.

Professional Status. This is also a variable which can usefully be employed to determine the level of information given to the largest group for public education and safety campaigns.

Influence of Alcohol. This information must be collected and fully taken into account in the statistics.

Severity of Injuries. Data concerning the different categories of victims must be given for all pedestrian accidents.

Purpose of the Trip (Way to Work, Shopping...)

**Direction of the Pedestrian Movement With
Regard to the Direction of the Vehicle**

**Data Concerning the Driver (or Drivers) Involved in
an Accident**

Age and Sex of the Driver. These variables can be useful for determining target groups of drivers for public education action and safety campaigns and may be used for choosing the best way in which to present information. This may also lead to recommendations concerning the period of validity of the driving license.

Driving Experience. These data could be recorded in number of years since the driver has held his driving license or in number of miles driven (but this doesn't seem to be a very valid data).

Influence of Alcohol

Purpose of the Journey

Data Concerning the Vehicle Involved

These data can be divided into three categories in order to obtain scientific support for making recommendations concerning the design of the vehicle.

Type of the Vehicle. Used for determining types of vehicles which are most often involved in pedestrian accidents. Could affect priority for regulations concerning the design of such types of vehicles.

Part of the Vehicle Which Has Hurt the Pedestrian. Can help in determining order of priority for regulations concerning design of vehicles.

Vehicle Lighting. There exists a need for more information concerning the respective advantages of using different lights (headlights or parking lights).

Data Concerning the Location of Accidents

The types of location usually recorded must be maintained, such as junction, crossing, off-side of the road.

In the data concerning black spots it is necessary to keep a distinct record of pedestrian accidents.

All the data concerning the identification of the site (lighting, volume of traffic, physical characteristics of the place and environment...) must be taken into account so that it can lead to site improvements specially related to the pedestrian safety.

Data Concerning the Time of Accidents' Occurrence

These data are most useful because they may provide a practical indication on which to base information to be given to the public and in particular serve as support for recommending the use of reflective clothes. For this purpose, the accidents' records should contain precise data on hour of occurrence and location (built-up area/not built-up area) of the accident.

PRESENTATION OF THE DATA

In many countries, data concerning pedestrian accidents are given in absolute figures. This is necessary but seems not to be enough. Other statistical presentations should be used as well, such as the number of victims by age group for every 100,000 inhabitants of this age group, severity rates.

Another most important point is the lack of crossings between the different variables (see category B). This could lead to a better and more accurate understanding of the problem of pedestrian accidents and could be used as support for practical solutions to the problem of pedestrian safety as pointed out in the preceding remarks.

MEASURE OF THE EFFECTIVENESS OF COUNTERMEASURES

One must not neglect the role of statistics in measuring the effectiveness of countermeasures. It should be taken as a rule that each time a countermeasure is adopted, its effectiveness is measured by an appropriate experimental design (e.g., pretest and posttest).

APPENDIX A

DEFINITIONS OF THE ECONOMIC COMMISSION FOR EUROPE (ECE) UNITED NATIONS

KILLED

Any person who was killed outright or who dies within 30 days as a result of an accident.

INJURED

Any person, who was not killed, but sustained one or more serious or slight injuries as a result of the accident.

SERIOUS INJURIES

Fractures, concussion, internal lesions, crushing, severe cuts and laceration, severe general shock requiring medical treatment and any other serious lesions entailing detention in hospitals.

SLIGHT INJURIES

Secondary injuries such as sprains or bruises. Persons complaining of shock, but who have not sustained other injuries, should not be considered in the statistics as having been injured unless they show very clear symptoms of shock and have received medical treatment or appeared to require medical attention.

Recommendations

CONCLUSION

Wide differences exist in the definition of road accident victims: "killed," "seriously injured" and "slightly injured." This problem which applies in particular to pedestrian casualties also exists for all road accidents.

RECOMMENDATIONS

- Member governments should agree about common criteria to define the category to which pedestrian victims belong and adopt, whenever possible, the definition of the Economic Commission for Europe (E.C.E.): which are already used in many other countries.
- Governments who agree to use these definitions should develop programs to ensure that they are applied throughout the country.
- Governments who do not find it possible to

change their own definitions, should establish conversion factors relating them to the international definitions. These conversion factors should be calculated for each category of road users.

CONCLUSION

Many data and cross data needed for obtaining an accurate understanding of pedestrian accidents are missing.

RECOMMENDATIONS

- Governments should develop uniform sets of data that will increase the comprehension of the causes and consequences of pedestrian accidents.
- Governments should carry out pedestrian and driver behaviour studies as one approach to increased pedestrian safety planning.

PSYCHOLOGY

Summary Of Responses To The NATO-CCMS Pedestrian Safety Questionnaire

Recommendations

**Countermeasures In The Field Of Human Factors In Relation
To Pedestrian Behavior, Regulations And Law Enforcement**

Rules Of Conduct For Pedestrians And Motorists On Or Near Zebra Crossings

Statement On Short-Term Pedestrian Safety Measures

Summary Of Responses To The NATO-CCMS Pedestrian Safety Questionnaire

INTRODUCTION

The following replies were provided for analysis:

- Belgium
- France
- The Netherlands (two replies)
- Sweden
- Turkey
- United Kingdom
- United States

The information provided was not suitable for meaningful statistical analysis. Instead, it seemed more appropriate to review the responses, summarize the general trends and consistencies and point out noticeable exceptions or unusual actions.

Following are the main questions, followed by our attempt to give the feeling of the replies.

PSYCHOLOGY

Please identify existing programs (activities) in your country that are designed to improve the future behavior of pedestrians. For example:

Are there any measures in your country, or have recommendations been made, to have pedestrians cross roads in groups on their own initiative rather than individually?

No present measures. One attempt, in 1961, to advise the elderly to cross in groups was reported, but little attention was given to it.

For the most part, the experts are doubtful about the effectiveness of this approach. On the one hand it may be difficult to get "individualists" to give up their freedom to cross by themselves without waiting for others. On the other hand, if they do adopt this procedure, pedestrians may become less attentive and have a false feeling of security when crossing in groups.

Is road-traffic training given at school?

All countries give some road-traffic training in school. The nature and extent varies from country to country, and in many cases, it varies from school to school within a country. In general, effective information is lacking.

Some points of interest are:

- Road-traffic training is compulsory for primary (elementary) grades (age 6-12) in Belgium and The Netherlands.
- It appears to be most frequently directed at these groups in all countries. Kindergarten, preschool children and nursery school children also receive this training in some countries.
- The time devoted to this training was reported as (a) a couple of hours a year primary, a day a year, secondary (b) 10 hours a year (c) 16-24 lessons a year (d) 30 minutes a week minimum.
- The areas covered include:
 - knowledge of traffic rules
 - crossing procedures
 - traffic tables, signal tables
 - awareness of traffic situations
- For the most part, traditional teaching methods and materials (e.g., printed materials) are used, but sometimes practice in a real situation is given, and there are some model areas or "safety towns," (see below).
- The only effectiveness data submitted were from the U.K. who stated that for the "green cross code" developed last year, "early results have shown in an accident saving for children of approximately 8 percent."

Does your country have model traffic-training areas for children?

All respondents indicated that they had model traffic-training areas. The number of parks or areas is from 10 to 20 in each country. Belgium and France have about 10 additional mobile parks. Training is given by police and/or teachers. The expert opinion was not enthusiastic, although no one suggested doing away with this method. No results were submitted, but Sandels' work was noted.

It was pointed out that this method does not reach many children and that it may be too artificial.

In The Netherlands, some have disappeared; while in Turkey 12 more are planned.

Are there manuals for parents to educate their children to cope with traffic?

About half of the respondents indicated that some materials were distributed to parents, but these were more limited than a manual. Belgium uses a set of folding views showing how parents should behave with children; The Netherlands reported three published leaflets; and the U.K. indicated that the "Green Cross" code was distributed. In Turkey, pamphlets to families cover the need for child pedestrian education.

If b) and/or c) exist, please indicate if there exists a training for teachers?

Although compulsory training for teachers was reported by The Netherlands, the reports from the rest indicated that there was little training for teachers or police and it was not highly organized. There was total agreement that training is inadequate. It was specifically noted that it does not reach enough people.

Does your country have a system for taking children to and from school?

There appears to be some system, for some children in most countries. Most reported using traffic wardens or patrols, usually adults. The U.K. reported that experiments using senior pupils (ages 16-18) as patrol wardens seem to have been successful. Most reported using buses, at least in some cases.

Does your country have courses to accclimate old people to present-day traffic conditions?

Of seven countries responding, three said yes and three said no, while one said it was not considered separately.

In Belgium, it is theoretical with a movie sponsored by the National Safety Council. The purpose is to change attitudes (by making them aware of danger and their responsibility) and behavior (by giving information about how to behave in different places).

In some places in The Netherlands lectures with slides and films are given, in others they receive three half-day sessions consisting of two lectures with slides and films and one practice session at regular crossings. This is conducted by the Pedestrian Organization which, in conjunction with other organizations, publishes materials on how to conduct a course. Materials for the elderly include specific dangers and advice.

Sweden reported primarily theoretical training with small group training to a low extent. The Pensioners' National Organization is the source of some materials.

Please identify existing programs (activities) in your country that are designed to improve the future behavior of the driver, so that pedestrian casualties are less likely.

About half indicated some attempts to improve driver behavior specifically with respect to pedestrians, but it appeared to be rather limited. Mass media campaigns were reported by Belgium, The Netherlands and Sweden, and the U.K. reported the use of TV films. A set of legal rules were presented by Belgium and the United Kingdom. For the most part, these appear to designate when the pedestrian has priority or the "right-of-way," but overtaking and parking restrictions are included. (Little information on enforcement was given.)

The use of driver manuals was also noted.

Please indicate any programs (activities) designed to enhance the pedestrian (driver) capability to respond in time by providing him better information. For example:

Have regulations or recommendations been made in your country requiring pedestrians to give a signal to motorists that they wish to cross the road?

Most responded no. In Belgium the raised arm signal was recommended during a safety campaign, but it was pointed out in that reply and others, that the pedestrian must still be attentive. The negative opinion appeared due to a fear that the driver might not respond, but the pedestrian would assume he would. France abandoned the raised arm because drivers did not respond.

Is special safety clothing provided in your country for wear by child road-users?

A number of countries recommend light, fluorescent and/or reflective clothing but recommendations were somewhat different in each and there does not appear to be much organized activity in this regard. In the U.K., dark and light clothing was recommended so as to be visible and to contrast with different backgrounds. It was also noted that for children exposed during the day, fluorescent clothing was preferred to reflective.

Also, one expert felt that orange fluorescent clothing should be reserved for patrols and wardens.

Please indicate any other program or activity, existing, planned or considered and rejected, that is designed to improve the probability of pedestrians or drivers avoiding a collision when they are in a potential conflict situation.

Crossing guards and wardens for school children, police protection at crowded crossing, and reflecting badges and tape were reported. For the most part, information was provided under previous responses.

Please indicate any activities designed to alert the public to the need for action to reduce pedestrian casualties.

All countries undertake some kind of safety campaigns of varying nature and extent that is difficult to summarize.

In general it appears that

- mass media are most widely used.
- to a lesser extent, specific organizations (clubs) may be involved.
- children receive the most attention, adults, especially the elderly, next, and drivers very little.
- there is a wide variety of efforts, with little pretesting or evaluation.

Some exceptions should be noted:

- The Netherlands reported that some campaigns are supported by research. The efficiency of slogans and TV spots are presented and the results of campaigns are studied.
- The campaign in the U.K., is part of an overall safety campaign directed at subjects which statistics showed were common causes of road accidents. Although the 8% reduction in 1971 for casualties in the under-15 years old category cannot be ascribed in total to the new code or the campaign, some positive effect is assumed.

In general, however, it appears that many safety campaigns for pedestrians are conducted with little advance study or evaluation, because the need is great even though our knowledge of what to do or how to do it is not so great.

Recommendations

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INTRODUCTION

Purpose

Knowledge about the causes of pedestrian accidents and the effectiveness of various proposed safety measures is limited. Research is needed to develop new pedestrian accident countermeasures of demonstrated cost-effectiveness. But because many are killed and injured each year as a result of pedestrian-vehicle collisions, some feel that some action must be taken without waiting for new developments.

The Pedestrian Safety sub-project of the NATO-CCMS Road Safety Project decided to divide the problem into a number of areas for which an analysis and recommendations could be prepared. Each report is to be based on the informed judgment of workers in the field as well as available scientific information.

The specific purpose of this report is to present *human factors* recommendations to member countries for action to be taken to reduce pedestrian casualties. In general, it is suggested that these recommendations be developed and tested prior to widespread application.

Scope

The objective of this paper is to cover the area of *human factors* broadly defined. The reduction of injury through vehicle design is considered in another project paper and is therefore not treated here. The term *human factors* has many meanings to different people. In order to give an indication of the intended scope of this report, a framework for viewing pedestrian safety action is briefly presented here.

There are three basic types of action that can be taken to reduce pedestrian casualties:

- Physically separate the participants (pedestrians and vehicles) so that a collision cannot take place (unless perhaps a vehicle crashes through a barrier).

- Develop safe behavior by the participants so that they avoid collisions.
- Given that a collision takes place, minimize the injury that results.

Human factors is primarily concerned with the second type of action — developing safe behavior to avoid collisions. There are three kinds of things we can do to develop safe behavior.

- Restrict the action possibilities easily available to the driver and pedestrian (e.g., make it easier to take a safer route).
- Enhance the capabilities of the participants to act safely (e.g., to detect and avoid threats).
- Enhance the predisposition (tendency) of the participants to act safely (e.g., educate them regarding the safe way, and motivate or train them to act accordingly).

This report will focus on activities that may be undertaken to reduce pedestrian casualties by achieving these ends.

Criteria for Recommendations

A number of factors were given consideration in the development of recommendations. The major criteria on which potential recommendations were evaluated are briefly noted below.

Expense and Cost-Effectiveness: Less expensive solutions were given precedence over other measures. If solutions involve high cost, those that could be implemented in stages are preferred. Perhaps most important, activities with the greatest (estimated) cost-effectiveness were given priority. Cost-effectiveness was considered in terms of cost per life saved or casualty avoided.

Feasibility, Realism and Ease of Implementation: These criteria are related to the practical realities of gaining acceptance for the specific actions or "countermeasures." One must realize that political and public acceptance factors may delay or make it impossible to implement a given countermeasure. Actions that severely penalize other groups in order to aid pedestrians are less desirable for this reason. (For example, countermeasures that severely restrict or limit traffic flow are not likely to be implemented. Certain types of parking limitations would also be difficult.)

Extent and Specificity of the Problem Attacked: The "pedestrian accident problem" is actually made up of a number of component problems and types of accidents. It was thought desirable to submit recommendations that dealt with specific identifiable aspects of the pedestrian problem. This would be helpful for two reasons. First, it would be easier to see where and when these actions should be applied. (A country or area could more easily select recommendations that are related to their specific problems.) Second, the requirement for treating specific problems is likely to help one recognize those recommendations that seem good on the surface but do not really treat an identified problem (i.e., it will help avoid recommendations that do not respond to a real problem).

With respect to the extent of the problem treated, two types of activities were given preference. One is activities or countermeasures that attack a type of accident or problem that represented a significant part of the pedestrian accident picture. Another type of activity or countermeasure might treat a small segment of the overall pedestrian picture, but that segment could be readily identified and isolated and thus the countermeasure recommended could be applied in a very cost-effective manner. (An example of this is the bus stop related pedestrian accident that has a specific cause and an inexpensive solution.)

Supporting Evidence: Perhaps most important of the criteria for selecting or developing recommendations is the nature of the evidence that supports the belief that the recommendation will be effective in reducing pedestrian casualties. The basis for recommendations can vary from scientifically derived empirical data demonstrating effectiveness, to intuition based on a review of the most obvious features of the pedestrian problem.

The preference for evidence was as follows (ranked from "best" to "least desirable"):

- Scientific evidence that an activity has been associated with a reduction in casualties, in comparison with an adequate control group or area.
- Evidence from the study of causes of specific accidents that the cause being treated is, in fact, responsible for pedestrian accidents. In addition, the effect of the recommended action on the cause must have a strong logical basis.
- Evidence that the action proposed has been associated with a reduction in accidents over a period of time (without control data).
- Evidence that the suspected "cause" being treated

is associated with higher accident frequencies, and a strong logical basis for believing that the recommended action will effectively treat the "cause."

- A logical case for a given activity, based on the tasks and operations involved in the traffic system. (For example, action to give pedestrians larger gaps in traffic by changing traffic signal timing.)

Although it would be desirable to limit recommendations to those that could be supported by evidence of the first type, this is not possible because of the present state of scientific data. An attempt has been made to limit the primary recommendations to those supported by the first two types of evidence. Most of the *primary* recommendations are based upon the specific accident evidence as described above.

It should be noted that differences in conditions or environments among nations may, in fact, limit the generalization of evidence from one country to another. It is thought that this is most likely to cause problems in evaluating proposed action and suspected "cause" evidence.

Number and Classes of Recommendations

When the state of knowledge is limited, and there is little basis for choosing among alternatives, it is tempting to list all possible actions and let the reader choose what he likes. However, it was felt that responsibility for the evaluation and selection of alternatives was at least implied in the assignment to prepare this paper. Thus, two steps have been taken:

- Recommendations have been made selectively. Not every possibility has been listed; only those to which serious attention should be directed have been listed.
- Recommendations have been divided into two classes, primary and secondary. In general, the latter do not come out as well on the criteria described earlier, but are worthy of consideration, especially for those who may value criteria differently from the author (e.g., give more or less importance to any criteria). When possible, the reason for placing a potential action in the secondary classification is stated.

PRIMARY RECOMMENDATIONS

Regulation of Specific Hazards

The legal and enforcement system can probably be used effectively to reduce casualties associated with

some specific hazards that are infrequent enough to be controlled.

Bus Stop Location: One type of pedestrian accident involves pedestrians who are struck as they step from in front of a bus that obscures the vision of both pedestrian and driver. Often the bus discharges passengers just before it enters the intersection. Discharge locations should be regulated so that the bus stops at the far side of the intersection, or otherwise, so as not to interfere with detection of pedestrians by drivers.

Street Vendors: Mobile vendors, particularly ice-cream trucks, are associated with a particular type of pedestrian accident in which children running to and from the truck are struck by other vehicles. Regulations should require such vendors to dispense goods as close to the side of the road as possible and to activate a warning sign with blinking yellow lights to alert motorists to the potential hazard.

Road Work Sites: In order to protect workers who must perform activities in the roadway, legal regulations combined with enforcement and education are needed to ensure correct safety practices including the use of properly placed warning signs and signals sufficiently in advance of the work site.

Selective Parking Control, Regulation and Enforcement

Parked cars are a significant contributing factor to a large portion of urban pedestrian accidents. The primary factor is the interference with driver and pedestrian vision. Steps should be taken to remove parking where it is most dangerous, or to rearrange parking so that it tends to increase the capabilities of the participants (pedestrian and drivers) to detect each other and avoid a collision.

Prohibition and Enforcement: An enforced prohibition of on-street parking in urban areas would be an effective countermeasure, but in many cases it is not feasible because it conflicts with other goals — social and economic. However, selective use of this approach should be tried. To the extent possible, on-street parking in high incidence urban areas (usually the high density residential areas) should be restricted. It may be possible to restrict it during the most dangerous hours (1500 - 1800). For example, it may be possible to prohibit parking on one side of the street on every fourth block. The point is that any enforced restriction is likely to help.

Attention should be given to newly developing areas, where it may be easier to implement a

restriction. For example, prohibiting on-street parking in an area about to be developed for single family homes would probably result in sufficient off-street spaces being provided by the builder. However, it should be recognized that newly developed areas are not the high incidence areas for pedestrian accidents.

Diagonal Parking: A significant problem involves children darting from between parked cars. Resulting accidents usually occur on residential streets during the day. The analysis of the problem has shown that the main items to be attacked and overcome are: (a) a risky pedestrian course — exposing him to view briefly; (b) failure of the pedestrian to search and detect; and (c) parked cars which interfere with driver and pedestrian vision.

An innovative potential countermeasure that is directed at this problem is parking redeployment. Two steps would be taken on certain one way streets in *selected residential locations*. First, parking would be removed from one side of the street, probably the left. Second, head-in diagonal parking would replace parallel parking on the right. In appropriate locations this would accomplish the following. Visual obstructions would be removed from the left side of the road giving the driver an increased view and more time to detect and react. The diagonal parking would provide a physical control and would tend to slow down the pedestrian as he ran across the street, but even more important, would angle him into traffic and direct his field of vision more in the direction of the threatening vehicles. Also, he would be able to execute evasive action more readily than when crossing directly across the street. Approaching on an angle would let him change course to avoid a collision, rather than having to stop. Finally, it appears that the average driver maintains a greater clearance from cars parked at an angle¹, thus improving his view of pedestrians entering from the parking side.

Because this is an innovative countermeasure, it offers greater potential as a solution to a stubborn problem, and at the same time will evoke some resistance because it disturbs commonly accepted ways of handling on-street parking. Some legitimate questions can be raised which should be answered, relative to traffic flow, parking accidents and public acceptance. Previous reports about accidents and

¹ Johnston, Bryan K. Angle vs. Parallel Curb Parking: "Time and Street Width Required for Maneuvering." A condensation of a research report. Division of Transportation Engineering, University of California, Berkeley, 1960.

diagonal parking have dealt with its use in business areas rather than the kind of application presented above. The data were gathered 20-35 years ago. (Changes in vehicle design and driving habits could change present day results.) Although most showed a reduction in parking accidents when parallel parking replaced diagonal, most studies had no control or sufficient baseline data for drawing firm conclusions about the cause. The effect of parking redeployment on parking accidents can and should be determined. However, even if this countermeasure were to increase auto-auto accidents, it still might be worth it. (A trade of personal injury accidents for property damage accidents appears to be generally acceptable.)

With respect to traffic flow, it has been reported² that for angle parking it takes the average driver 12 seconds to back out of a stall and proceed forward in the traffic lane; for parallel parking the average driver takes 32 seconds to back into a stall and clear the traffic lane. For the 85 percentile, maneuver time was 17.4 seconds for angle and 53.5 for parallel. Thus, delays from parking maneuvers would probably be reduced.

Although the selective use of diagonal parking as a countermeasure is based on an analysis of specific causes of a frequent type of pedestrian accident, its value has not yet been demonstrated. However, there is a sufficient basis for recommending that selected applications be made to test its effectiveness and related consequences.

Child Play Location and Supervision

Reports from various countries show that young children are frequent victims.³ Furthermore, most of these accidents occur in the afternoon. Frequently, the children are engaged in a play-related activity. Action is recommended that will result in children playing in locations where they are less likely to be struck, primarily because of improved capabilities of the participants to detect each other. A number of specific activities should be considered, including:

Identified Play Streets: Certain streets should be carefully selected for use as play areas for children during designated hours. These locations should be limited in number. Locations on crowded residential streets, usually surrounding the central business district, are most likely to be high-incidence areas for

which this action is appropriate. Special warning should be given to the motorist by means of special signs and perhaps a movable "speed bump." The street should be identified as a play area only during after school hours in the afternoon (1500-1700). Flashing warning lights on warning signs could be activated at those times.

Children who play on the street should be taught how to organize their games to include the assignment of responsibility to a child for warning of approaching cars.

The objective of this approach is *not* to geographically separate pedestrian and vehicle, but rather to increase awareness and the probability of avoiding accidents. It should be noted that in one study of urban pedestrian accidents, few children who were struck had been playing in the street prior to the accident; many were playing on the side and then darted out into traffic.

Play Location Supervision: A local official, perhaps a police officer, should be trained and assigned to high-incidence areas to influence the location of child play activities so that they are more likely to be detected by motorists, or are less likely to dart into traffic during the course of their play activities. (This official might also perform other pedestrian safety related functions like parking regulation enforcement or child safety education.)

Early School Pedestrian Program

Because of the high involvement of young people in pedestrian accidents, and the special opportunities to reach this group through the school, an early school program is clearly desirable. (In this case, "early" means as early as possible upon entering school.)

Failure of pedestrians to adequately search and detect the threatening vehicle, along with their selection of a hazardous course that exposes them to view for only a short time before the collision, have been identified as important causal factors in urban pedestrian accidents.⁴

The purpose of the "early school pedestrian training" program is to (a) reduce hazardous entries of unsupervised children into streets and (b) increase their detection of threatening vehicles.

²Ibid.

³Smeed, R.J., Aspects of pedestrian safety. *J. Transp. Econ. Policy*, 1968, 2 (3), 255-79.

⁴Snyder, M. B., and Knoblauch, R. L., Pedestrian Safety: The Identification of Precipitating Factors and Possible Countermeasures. Volume II - Appendices. Operations Research Inc., Silver Spring, Maryland. (NHTSA:DOT HS-800 403) 1971.

It is clear that new approaches and methods are needed. Research and development is needed to achieve the necessary methods, techniques and materials. However, two approaches, new to pedestrian safety education, appear promising and if properly developed should yield positive results.

Simple Specific Cause and Avoidance Education: For three or four specific pedestrian accident types in which there is a large involvement of children, the salient causal events and avoidance/corrective action should be learned by children. The approach should be simple, non-moralistic, short and direct. It should focus on "how kids get hurt and how you can avoid being hit." It should be realistically consistent with the existing motivations of children to the extent possible (e.g., it should recognize that children will play in the street, and sometimes cross on the red). This part of the program could be implemented relatively quickly.

Detection Training: The specific objective is to produce the physical responses at the appropriate times by children in danger, or about to be threatened, that will result in earlier detection, thereby avoiding accidents. This is different from education in the traditional sense, since the special training is aimed at conditioning an automatic physical response or habit — turning the head — rather than trying to get the child to think of what to do as he is running out into the street.

The approach is to use techniques of "reinforcement" of behavioral responses that have been given considerable attention by behavioral scientists in the past decade with promising results. The child would be trained in a situation approaching the real life situation in which the detection response is needed. The particular training methods require some development before a program can be launched. However, some particular directions appear promising and plans are being made to develop operational methods. Two particular techniques should be considered: (1) game situations that involve detecting a target (simulated car) while running over the curb chasing a ball (or other similar situations) and (2) individual visual simulators.

A variation on this approach, which would make it more effective, requires the cooperative efforts of educators and engineers. It consists of special training and curb marking in high incidence areas to condition children to look toward traffic as they approach the curb.

The special curbside markings would provide the trigger to set off this automatic response and help to

maintain the habit. Alternating colored diagonal stripes facing at a 45 degree angle towards the traffic is a possible marking. The heavy incidence of children dart-outs in high density center city residential areas helps to localize this application. It is hoped that further research will permit an accurate pinpointing of the high risk streets.

This second part of the program could be integrated with the first part (specific cause and avoidance education) as soon as the development is completed.

Public Education on Specific Causes and Avoidance Procedures

It is felt that public education can be an effective action, but only if very careful attention is given to the content of the information supplied. Broad generalities and unrealistic requests for action (e.g., always cross on the green) should be avoided. Instead, the public should be provided with specific information on (a) situations and behaviors which have been found to lead to pedestrian accidents and (b) realistic actions and methods for them to avoid such situations or get through them safely.

In the U.S., the following distinctive pedestrian accident types have been identified and appear as good candidates for coverage in an education program:⁵ dart outs, intersection dash, multiple threat, vehicle turn with attention conflict, freeway crossing, vendor, and bus stop. They account for an estimated 57% of urban pedestrian accidents. From the literature, and discussions with experts in other countries, it appears that the first four, which account for the bulk of the accidents, are not unique to any one country.

It is recommended that countries (a) determine the most frequent accident types and the target groups and situations associated with them; (b) develop concise and simple explanations of the problem and realistic avoidance actions acceptable to the public; and (c) use existing channels of communication to the public, to deliver these messages.

Driver Licensing and Training

The same approach as that described for public education should be followed for driver training and licensing, except that the information should be limited to that specifically applicable to drivers.

⁵ Snyder, M. B., and Knoblauch R. L. op cit. See Appendix for brief descriptions.

OTHER ACTIONS TO BE CONSIDERED

Pedestrian Information and Signals

It would be an error to assume that the installation of traffic signals in general, and pedestrian signals in particular, will "solve" the pedestrian accident problem in any given location. *Traffic* signals may be appropriate as a pedestrian accident preventive device in locations where pedestrians are struck because heavy traffic flow leaves inadequate gaps and pedestrian risk taking increases. *Pedestrian* signals, on the other hand, should function to provide the pedestrian with information that will help him to avoid the dangers in crossing the street.

The use of pedestrian signals is growing and the information provided by the common "walk-don't walk" signal is minimal. The fact that "don't walk" does not mean that at all, is probably not serious because people can be expected to learn that it means "don't leave the curb." However, the signals give advice rather than information and many people do not accept advice.

The red signal to a driver gives him advice and information. It not only tells him that he is legally advised not to go, it also tells him that someone else is being told to proceed across his path. For the pedestrian, however, a "walk" sign is only advice. Vehicles may or may not be told to cross his path at the same time. In many cities, vehicles are permitted to cross the pedestrian's path while the "walk" sign is on. In one city "walk" means that no vehicles are permitted to cross the pedestrian path. In a second city, a constant "walk" means no vehicles are permitted to cross the pedestrian path, while a flashing "walk" means that the pedestrian is subject to some legal vehicle threat. Unfortunately, almost no people in the second city are aware of this distinction between the constant and flashing "walk" signal.

The pedestrian should be given better information about the threat he faces at a signal. He could be informed of the three basic conditions: (1) heavy, fast-moving, or direct traffic flow across the pedestrian path; (2) turning and/or lighter traffic across the pedestrian path; or (3) no legally permitted traffic across the pedestrian path.

These conditions are somewhat comparable to red, green and amber (RGA). Perhaps the pedestrian should have a distinct RGA, obviously different enough not to be confused with the vehicle signal (e.g., a sign that flashes the word "pedestrian" or a figure of a person in the appropriate color).

Another important point about traffic signals and

pedestrian behavior concerns the timing. A certain number of accidents occur because long waits for the proper signal sometimes make pedestrians impatient. They then disregard the signal and attempt a crossing. In some locations, longer than usual waiting periods are involved in order to move heavy traffic volumes. However, it must now be recognized that this may induce pedestrians to take risks because they are impatient. Standard time periods cannot be recommended on the basis of present data. The best specific treatment will depend on the individual nature of the intersection and its vehicle and pedestrian volumes. It is recommended that local traffic engineers review intersections with the longer pedestrian waiting periods, especially in commercial and multifamily dwelling areas surrounding the central business district, and consider the following possibilities:

- Resetting cycles to bring pedestrian waiting time in line with the norm, or lower if other considerations permit
- If rush hour volumes do not permit complete retiming, reduce pedestrian waiting periods during non-peak hours. (Many "dashes" across urban intersections occur before or after the 1600 to 1800 rush period.
- Provide a signal indicating the waiting time remaining to green. This could be a numeric countdown signal giving the seconds remaining, but need not be; color codes or 10 second intervals could be used. Such a signal could be integrated with the wait-walk, or RGA type pedestrian signals.

Pedestrian signals are recommended for use in downtown and other areas where there is heavy (continuous) traffic flow and pedestrians usually cross at intersections. Signals must have a *uniform meaning* and the public must be educated so they know the specific meaning of the signal they see.

Crossing Simplification

Some of the countermeasures usually considered have the effect of simplifying the crossing situation. It would be expected that the fewer directions from which threatening traffic can arrive, the more likely the pedestrian will be able to handle the situation. The positive effect of *one-way streets* in simplifying pedestrian crossings, reducing pedestrian accidents, and improving traffic flow is documented elsewhere⁶

⁶Automotive Safety Foundation. *Traffic Control and Roadway Elements*. Washington, D.C., p. 72.

and is apparently not disputed. The existence of many two-way streets, however, makes it desirable to call attention to this measure once again.

Another approach to crossing simplification is mentioned here for further analysis and consideration. That is the use of *non-intersection pedestrian crossings*. This would reduce the threat from turning vehicles. Mid-block signals and corner pedestrian barriers might be required. Difficulties with traffic flow might make mid-block signalization difficult, but it may be feasible in some locations. A crossing some feet in from the intersection would mean that a pedestrian only has traffic coming from his side rather than from behind on his side and in front of his side. Again, this approach is suggested for further analysis and testing rather than immediate implementation on a widespread basis.

School-Home Crossing Protection

Need for activity in this area depends on the extent of the problem in any given jurisdiction or country. In the U.S., for example, improvements in this area of activity should not be given high priority, since relatively few children are struck going to and from school.

Two basic steps are involved. One is to provide adult supervision and protection at dangerous crossings used by children going to and from school. The other is the selection of the safest route home for each child to use, along with the needed instruction to cause him to use it.

Pedestrian Visibility Devices

Many fatalities occur at night and visual detection is an obvious requirement for avoidance. Thus, improved illumination or the use of reflective surfaces on pedestrians are common recommendations. It is our opinion that these measures can certainly help, but that there are serious questions about their cost-effectiveness.

First of all, all nighttime accidents are not due to poor visibility resulting from darkness. Some nighttime pedestrian accidents occurring in total darkness would still have occurred at noon. One attempt to compare causes of night and day urban pedestrian accidents failed to find meaningful differences. However, data were drawn from urbanized areas where street illumination was usual. This brings us to the second point. The present level of illumination will obviously influence the degree to which improvements could be cost-effective. In cities

where street illumination is prevalent and "fair to good," the effectiveness of reflectorized devices, or new illumination methods could be minimal. In the case of rural pedestrian accidents, the improvements might be striking. Although our knowledge about the rural pedestrian accidents is limited, it appears worthwhile to identify those target groups who are expected to be rural pedestrians at night, and explore methods for selectively encouraging the use of reflectorized devices. This recommendation should be reviewed as better information becomes available.

CONCLUSION

This paper has presented *human factors* recommendations for action to reduce pedestrian casualties. Most of these recommendations can be put into effect in a relatively short time period. The main barriers to obtaining the potential benefits they promise are inertia and the lack of a dramatic presentation to stimulate action. An appropriate next step would be for at least two or three countries to mount demonstration projects using recommendations from the various papers presented at this meeting. Such projects should provide for the collection of evidence regarding the effectiveness of the measures taken. These projects could then serve as prototypes and stimuli for concerted action to reduce pedestrian fatalities and injuries.

APPENDIX

ESSENTIAL ASPECTS OF SELECTED URBAN PEDESTRIAN ACCIDENT TYPES

DARTOUT

A pedestrian, not in an intersection crosswalk, appears suddenly from the roadside. His quick appearance and short-time exposure to the driver are the critical factors. The pedestrian often may be running, and parked cars often obstruct vision, but neither need be present if the basic condition of sudden appearance to the driver's view is met.

INTERSECTION DASH

A quick crossing attempt at or near an intersection.

VEHICLE TURN — ATTENTION CONFLICT

Driver, attempting to turn into traffic, attends to traffic in one direction and strikes pedestrian in other direction.

MULTIPLE THREAT

Pedestrian is struck by a second or third vehicle after other stopped cars which blocked the vision of the striking vehicle, permitted the pedestrian to cross.

BUS STOP RELATED

Pedestrian is struck after he steps out from behind a bus at a stop.

VENDOR — ICE CREAM TRUCK

Pedestrian is struck going to or from street vendor.

NON-PEDESTRIAN ACTIVITY IN ROADWAY

The victim is performing a specified activity in the roadway such as repair work (e.g., going into the street to retrieve an object or avoid a danger is not included).

Countermeasures In The Field Of Human Factors In Relation To Pedestrian Behavior, Regulations And Law Enforcement

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EXISTING MEASURES

Everybody, in town and country, is a pedestrian road-user almost daily. His behaviour is then governed by his optical impressions, habits and experience rather than by traffic-control regulations. A pedestrian is often an unpredictable road user. In terms of vehicles, he is very maneuverable, accelerates fast and can stop very quickly. He can also move forward, backward or sideways. Differences in age, sex and destination are reflected more clearly in pedestrian traffic than in wheeled traffic. Because of all this, pedestrian traffic is more difficult to fit in a clear and simple pattern than wheeled traffic. There is an absolute lack of good methods for recording the characteristic features of pedestrian flows.

Measures for preventing or reducing the number of conflicts between vehicles and pedestrian traffic have taken the shape of pedestrian crossings.

A pedestrian crossing gives the pedestrian a certain measure of legal and/or physical protection.

Such crossings can be subdivided into various types:

- Zebra crossings;
- Light-controlled crossings; a variant of these is the crossing with push-button lights;
- Pedestrian bridges and subways.

Statistical figures show that the number of pedestrians among road casualties is increasing less rapidly than the total number of casualties recorded. It must not be concluded from this, however, that pedestrian traffic has become safer. It is more likely to be due to the much quicker increase in the number of other road casualties. This, in turn, is largely due to the more rapid increase in the number of private cars (and their mileage), as compared with the increase in the number of pedestrians based on the growth in population.

It is also remarkable that the introduction of the zebra-crossing regulations in most countries hardly seems to have affected the pattern of accidents.

As is often customary, the places where pedestrians come into conflict with motor vehicles

are sub-divided into zebra crossings, light-controlled crossings and elsewhere. The international literature invariably shows the same differences of which table 1 is an example.

Table 1
Relative Risk When Pedestrians
Cross Roads

(SOURCE: R.R.L., 1965)

Place		Relative risk
at, or within 20 yards of a junction	on light-controlled crossing	0.20
	on zebra crossing	0.85
	elsewhere	1.25
more than 20 yards from a junction	on zebra crossing	0.22
	elsewhere	1.00

This table shows that zebra crossings involve three times the relative risk of light-controlled crossings. But zebras are comparatively safer than elsewhere.

There are no demonstrable indications that this pattern is different between countries. Nor is there any reason to suppose that the introduction of the regulations caused any movement in the relative safety figures. Legal protection does not, in fact, mean accident protection. An interpretation of the zebra-crossing regulations causes constant problems for both pedestrians and motorists, while the police can hardly check these interpretations, it will be difficult to bring about even a low percentage in overall pedestrian safety.

As a number of traffic experts doubt the safety effect of zebra-crossing regulations, supplementary means are being sought of making zebra crossings more conspicuous after dark.

- There are a number of possibilities of making zebra crossings more conspicuous such as: signal lights in the road surface, flashing lights, special lighting, or colored light.
- According to Schreuder (1964) it is essential to have good street lighting or good lighting of the zebra crossing itself. If street lighting is good there is no need to light the crossing as well.
- With bright overhead zebra-crossing lighting limited to the zebra path, there is a danger of the

pedestrian believing he is clearly visible when he is often not so. This gave rise to the idea of the silhouette effect.

Depending on the standard of street lighting, each zebra crossing should have either a negative contrast between pedestrian and background (i.e. pedestrian dark against the road surface) or a positive contrast. The minimum contrast is a luminosity ratio between pedestrian and background, or vice versa, of at least 1.3¹).

If there is no continuous street lighting, a positive contrast is cheaper to achieve in practice than a negative contrast. In the latter case, 130 meters of lighting on both sides of the crossing is necessary. And with a wet road surface the negative contrast is difficult because the background can hardly be made uniformly bright.

Giovanelli, Blevin and Wright (1962) propose that zebra crossings needing additional lighting should be provided with spotlights shining from the direction of oncoming traffic so that motorists could see pedestrians in direct light. They want to improve the silhouette effect (positive contrast), which their system makes possible even in bad weather. They believe that special lighting is advisable for frequently used zebra crossings so that pedestrians will stand out more against the background.

In order to obtain proper lighting, the Street Lighting Committee² advises a lighting system in which the lamps, seen from the direction of driving, are fitted before and over the crossing. The main thing is to provide enough horizontal illumination of the crossing so that the crossing itself is clearly recognizable. At the same time there must be enough vertical illumination to observe the pedestrian using the crossing.

As already noted, road-surface illumination is very important in conjunction with crossing lighting. The Netherlands Illumination Association (1967) recommends an average road-surface illumination of at least 1 cd/m² over a length of about 100 meters at both sides of the crossing. In order to make the crossing more conspicuous, other (i.e. additional) light sources besides streetlights can be used with horizontal (E_H) and vertical (E_V) illumination. The E_H and E_V values depend on the strength of the streetlight, the criterion for which is the average

horizontal illumination ($\bar{E}_{H,OV}$). E_H and E_V should be at least equal to $5 \times \bar{E}_{H,OV}$ and certainly not less than 40 lx. If $\bar{E}_{H,OV}$ is greater than 20 lx lighting in situ is necessary.

The SWOV (The Netherlands) has already pointed out (in 1967) that additional zebra lighting is needed only if the crossing is relatively very dangerous and only if this danger is indeed due to the lack of adequate street lighting. The SWOV also pointed out the danger of additional lighting for some crossings, which may reduce the value of those without it.

It would be better if the entire road situation (crossing and junction) could be uniformly lighted. Most crossings are at junctions. Additional lighting for the crossing often worsens the lighting at the junction, which is not advisable. Additional lighting could, however, be provided for crossings not located at junctions.

Green Waves for Pedestrians

The rapid growth of traffic will create an increasing need for additional facilities in the form of new roads and road improvements and for more efficient traffic control. In practice, however, such facilities are not always possible because of lack of space or shortage of funds.

It is possible, however, to improve the efficiency of the existing road system. As the efficiency of the road system is largely determined by the capacity of intersections, traffic control installations have been designed and operated in Delft (The Netherlands) which make the very most of the available traffic space.

The prime requirements for traffic control will be briefly indicated.

Performance* Traffic control performance must be maximal; it is at its maximum when lost time is at a minimum.

Lost time relating to the times when intersections are not in use by traffic is minimal, if, with the correct green-phase combination and green-phase sequence, the position of each individual green-phase is related solely to the end of the queue of the preceding conflict phase or phases.**

*Hakkesteeft (1970) uses the term 'performance' for the notion of capacity. Performance of a traffic control system is defined as the number of vehicles (including pedestrians, cyclists) able to cross the intersection per unit of time.

**Conflict phases are the green/amber phases of directions from which traffic flows are not admitted to the intersection at the same time.

¹"Report on Spa Conference of Lighting Experts," October 1967.

²"Meeting of Street Lighting Committee of the Netherlands Illumination Association," 5th November 1965.

With any other system a smaller number of vehicles will be able to cross the intersection owing to the lost time being greater.

Safety in Relation to Performance. Safe traffic movement is mostly achieved by "safeguarding" the conflict situations against each other and by choosing the times of the clearance phases so that no first vehicle collides with any last vehicle. In this context, a pedestrian is also considered as a vehicle.

Traffic control meeting these requirements is possible only with efficient division of the time and space factors for the benefit of the intersecting traffic flows. Owing to the big fluctuations in traffic patterns, in the form of traffic volume and its structure — which varies greatly in The Netherlands — there are very many combinations of these factors. The possibility of reacting to these combinations determines traffic control efficiency. For every moment a traffic light is unnecessarily green for a given direction, cars and pedestrians are probably waiting unnecessarily for the other directions. All these possibilities and requirements are built into the Delft flexible traffic-light system, for cars, public transport (trams and buses), cyclists and pedestrians (Hakkestegt, 1970). The system is adapted to the density, nature and behavior of the various fluctuating traffic flows. In Delft, operation of the control equipment is not only traffic-related but is partly also provided with simple memory-decision elements for optimizing control and also for special priority facilities for public transport and pedestrians.

The bigger and more complicated an intersection is for wheeled traffic, the more complex it becomes to cross it on foot. Thus the pedestrian is forced to cross in stages and to wait on refuges between the flows of traffic. Many of them will not tolerate this, and will ignore the traffic signs and simply cross. Pedestrian-crossing lights which these road users regard as remaining unnecessarily red encourage offenses.

Within the Delft flexible traffic-light system priority is given to road-crossing pedestrians.

By pressing buttons the pedestrian reports to the traffic control equipment, which acts separately for each direction in order to synchronize the series of pedestrian crossing-lights and make one wait for the other if necessary. This not only cuts unnecessary waiting times for pedestrians, but also creates green waves for them so they can cross the complicated intersection in a single journey. The whole system is planned so that these pedestrian facilities do not adversely affect the capacity of the intersections.

Having to "report" to the control equipment automatically distinguishes between: "pedestrians" and "no pedestrians." If there are no pedestrians, wheeled traffic can carry on with minimum waiting times.

This initial experiment with green waves for pedestrians has the following advantage for them.

- As regards *convenience*, it is obviously more convenient for the pedestrian if waiting times are reduced to a minimum; this means even more to him in bad weather with rain or snow.
- The impression is that familiarity with the system induces people to obey it more (by not crossing when the light is red and not walking across near the pedestrian crossing) than they do at other controlled crossings, and therefore *safety* is also likely to become greater.

There is a definite impression that these green waves for pedestrians will have a favorable effect. The system will, therefore, be regularly extended in the future, especially where there are situations dangerous to pedestrians.

Pedestrian Bridges and Subways

In order to reduce the number of conflicts between pedestrians and vehicles to nil, the only (basic) solution is to separate pedestrian traffic spacewise from wheeled-traffic. Separation timewise in the form of zebra crossings and light-controlled crossings has proved inadequate.

Examples of this principle on a large scale can be found in The Netherlands in Lelystad, with subways; in the United Kingdom and several other countries it is found in "New Towns."

Traffic Training With Model Traffic-Training Areas (Traffic Gardens)

Besides the above-mentioned measures, there are measures taken in the field of education. In The Netherlands about ten model traffic-training areas are in use to train children to cope with traffic conditions, like many other countries do.

The basic idea is that children can be taught a number of rules of the road quicker and better in such a training area; it is also assumed that if proper behavior (conforming to the traffic regulations) can be taught, the child will behave in the same way under actual traffic conditions.

Research in other countries, especially by Sandels (1969), however, clearly shows that these traffic-training areas are not such a successful training

method. Prof. Sandels made two investigations into the effect of such instruction on children's mental behavior.

- Children, all aged 7, were divided into four groups:
 1. a group taught in training areas;
 2. a group taught in a school playground by simply marking lines on the ground and placing some traffic signs in position;
 3. a group trained under actual traffic conditions in the street;
 4. a group with no training at all.

Before being given any instruction, all the children were tested regarding their knowledge of relevant traffic situations and did a pedestrians' test in a simple situation in the street.

All the groups except (4.) were taught by the same teacher for the same length of time and in the same words.

In the after-period they were interviewed and given practical pedestrians' tests.

- The same experiment was made with infants aged 6. Both studies showed that by far the best method of teaching correct pedestrian behavior was in actual traffic conditions.

Next came the method in school playgrounds. The model training area was hardly better than for the control group with no training at all.

A number of obvious reasons why these areas are not a very successful training method are:

- Children do not see the same things as adults (the eyes of 6-year olds are only about 110 cm from the ground). In the training area everything is at child-height, which is unrealistic.
- Objects obstructing the view do not usually occur in such a training area, but do so in actual traffic conditions.
- Children concentrate on one thing at a time. In a training area they do this in simple situations, but lack the scope for a good over-all view of a real (complex) situation.
- Speeds in the training areas are very low. Research shows that children cannot estimate the speeds of approaching vehicles under actual conditions.
- Adults often think that children will behave in actual conditions as they ought to after having travelled the route a few times in a training area under supervision.
- There is a real possibility of children transmitting the game-playing conditions in the training to actual traffic conditions, which is not desirable.

It follows that on the basis of present knowledge, model traffic-training areas are unlikely to make a

pronounced, positive contribution to road safety; and certainly not for children up to, say, 8 or 9 years old. Nevertheless, if it cannot be proved that a measure is unsuccessful or if it is expected to be unsuccessful, its essential features will first have to be studied.

This is being done in Eindhoven (The Netherlands), in a well-equipped training area where the element of playing a game has been eliminated and where there are suitable training programs for children in the 1st to 6th grades of schools (both practical and theoretical). A TV camera records the children's behavior in miniature cars, on bicycles and as pedestrians, for subsequent analysis. It is intended applying this observation method to a number of children as from the first grade of school up to the 6th grade, i.e. for six years. The children go to the area five times a year, i.e. thirty times in total for 1½ hours at a time (¾ hour practical and ¾ hour theoretical).

Later, the information regarding acquired behavior in the training area and the effect in actual traffic conditions will be compared with control groups who have not been trained by this method.

EXISTING THEORETICAL STUDIES ON PEDESTRIAN BEHAVIOR, REGULATIONS AND ENFORCEMENT

In the distant past the pedestrian was the major road-user. But nowadays he plays a minor part in traffic and often he is not even regarded as a real road-user.

If one seeks to explain this situation, a number of differences between pedestrian and driver behavior emerge.

Characteristic Movements of Pedestrian Behavior

A motorist* as a road-user is bound by regulations and physical obstacles. The pedestrian, however, is far less tied to place and direction and acts in accordance with his immediate optical impressions, his habits and his past experience rather than traffic control regulations.

The behavior of a pedestrian as a road-user is often unpredictable. To speak in motoring terms: he is very maneuverable and can reach top speed or stop very quickly. And in doing so he can move forwards, backwards or sideways. Differences in age, sex and destination appear more with pedestrians than with vehicles.

*References in this report to "motorists" include all other wheeled traffic.

Pedestrians as a Group. The failure to recognize the pedestrian as a fully fledged road-user is partly the fault of the pedestrian himself.

The American Automobile Association (A.A.A., 1964) raises the aspect of pedestrians' behavior as a group: pedestrians are an unorganized group who carry on very few group campaigns like other interested groups (for instance motorists); the pedestrian is an individualist.

They demand little attention for themselves and have automatically accepted the responsibility for individual self-protection. They are often even apathetic about their own safety as road-users.

The Pedestrian's Attitude. The attitude of the pedestrian himself is difficult to change. As he is the weaker party in manifest conflicts with motor vehicles, efforts have been made to give him more rights by making new regulations (including zebra crossings, precedence over vehicles turning off). The pedestrian tends to accept the rights attaching to his position but not the duties. He does not regard himself as having to observe traffic rules.

Pedestrian/Motorist Social Relationships. It is worthwhile analyzing the social relationships between pedestrians and motorists in order to understand more about pedestrian behavior.

A number of aspects of the social relationship between pedestrian and motorist are:

- time;
contact between pedestrians and motorists lasts relatively longer than that between motorists. They thus recognize and know one another better and the social pressure to behave according to generally accepted rules will be greater.
- anonymity;
unlike the frequently anonymous contact between motorists, anonymity is lessened in pedestrian/motorist relationship. In fact, since contact mostly lasts relatively longer, it is possible for instance to distinguish sex and whether the person is harmless, etc. Because of this there will be more social pressure to behave according to the rules than there is among motorists individually.
- social power;
the possibility of compelling the other person to comply with generally accepted rules, however, depends on what social power one possesses. In the interplay between motorist and pedestrian the motorist, with the power of his vehicle, has an advantage over the vulnerable pedestrian, so that the latter will usually tend to make the best of things.

- route-dependence;
if the movement of motorists and pedestrians is obstructed, the motorist is more dependent because he has to stand still in the line of traffic and has a choice of few, if any, alternative routes. The pedestrian on the other hand has a host of alternative routes at his disposal in case of obstruction.
- the value of time;
the motorist has more notions of time (driving on time, covering a route in a given time) than the pedestrian. Losses of time thus inconvenience the motorist more than the pedestrian.

Being more dependent on the route and having a greater notion of time (and loss of time) may make the motorist put his social power to greater use in the behavioral influences between motorists and pedestrians.

Conclusions. The foregoing indicates that more restrictions (by means of regulations) can be imposed on pedestrians in order to minimize motorist-pedestrian conflicts.

Any measures should, therefore, be directed at the duties of the pedestrian rather than at those of the already heavily burdened motorist. The pedestrian must be conscious that he is a road-user as the others are and that the highway code is also made for him.

Research

In seeking the causes of accidents, it can be assumed that accident proneness is not increased or reduced merely by a number of technical aspects. Pedestrian and driver behavior will both help to determine the degree of safety. Behavior in this context means individual behavior as such and also behavior as influenced by a number of factors (the weather, planned journey time, road diversions, etc.). Information about these will increase our knowledge of road safety.

Pedestrian and Driver Behavior at Zebra Crossings. Pedestrian behavior may change as the years go by, as a study (R.R.L., 1965) of a single zebra in London has shown. The percentage of pedestrians using the zebra increased from 45% in 1948 to over 70% in 1959. This different pedestrian behavior on the crossing in question is ascribed to its having become more difficult to cross elsewhere, to changes in the crossing markings, and also to more rigorous enforcement of the regulations.

Research by Mackie (1962) showed that pedestrians are more inclined to use crossings of the zebra type. Here again, there was a change in the

behavior pattern of pedestrian movement with respect to the crossings. Of the total number of pedestrians crossing the street within 50 yards of a zebra, 78% actually used the crossing in 1961; in 1955 there were 67%. Notwithstanding an increase in the proportion of pedestrians using crossings, Mackie found no increase in the percentage or number of accidents that occurred there.

Utter (1949) and Sharfuddin (1959) showed that driver and pedestrian behavior can be (positively) influenced by introducing road markings.

In Switzerland (Wepf, 1966) research was undertaken into road-user behavior at zebra crossings, which showed that behavior differed according to the time of day, and also for pedestrians going to or coming from work, or going shopping or for an evening out.

In the town center, pedestrians stepped onto zebra crossing without giving a signal*, crossing the street in stages or responding to behavior which on the motorist's part was quite clear.

They rarely waited for a gap in the traffic because such gaps were rare.

Herwig (1965) found that pedestrians generally realize that they ought to give a signal when stepping onto a zebra crossing, but do not usually do so. Motorists are comparatively sympathetic towards pedestrians' signals. In fact they often point out that pedestrians fail to give signals. The number of motorists giving signals were slightly more than pedestrians, but on the whole still very slight. The driver in fact has less opportunity to give signals because of his situation.

Moreover, many drivers purposely refrain from giving signals or stopping, because following cars may collide with them.

Note: According to Herwig the pedestrian cannot therefore manage to simplify the complexity of many traffic situations at zebra crossings by giving signals to motorists.

Influence of Approaching Vehicles' Speeds.

Research by Cohen et al. (1955) related intervals of time for individual vehicles to pedestrians' decisions to cross the street. All pedestrians cross if the approaching vehicle is more than 10.5 sec away; 50% cross at 4.5 sec and fewer than 15% cross if the vehicle is within 1.5 sec away.

*In Switzerland, pedestrians are required to give a signal if they intend to use a zebra crossing.

Robinson (1951) found, however, that the interval of time for crossing in front of approaching vehicles is 7 sec for 50% of all pedestrians.

The R.R.L. (1965) showed by similar investigations that the pedestrian's decision to cross depends on the interval of time and not the absolute distance of approaching vehicles. There is a tendency to accept shorter intervals if the approaching vehicle's speed increases.

Moore (1965) came to the same conclusion as the R.R.L. He investigated whether a waiting pedestrian was likely to cross when vehicles reach a given distance away at various speeds. The hypothesis that the pedestrian estimates the time in which the vehicle will approach and allows himself a given interval of time is not complete, because pedestrians tend to cross in shorter intervals if the vehicle's speed is increasing. This means that pedestrians take bigger risks the faster the vehicles drive. Moore found that the pedestrian does indeed assess approaching vehicles' speeds and a gap in the traffic is not the main factor.

Similar tests, but related to vehicle lighting, were made by the SWOV (1969). The behavior of road-crossing pedestrians (expressed as necessary crossing time and frequency of wrong decisions) under laboratory conditions with a single car approaching on an otherwise empty road does not measurably depend on the brightness of a car's lights. Nor does it depend on the average street-lighting level. Wrong decision in practice — especially crossing wrongly when a car using side lights is approaching — must therefore be the result of disturbing influences, such as the presence of cars with very bright lights.

Jacobs (1965) comments in this connection that the time required by the road-crossing pedestrian does not change if there is a zebra crossing. Only the speed of approaching vehicles changes if zebra markings are introduced.

Herwig (1965) found that the speed of motor vehicles depends on the number of pedestrians standing at the pavement edge. Speeds are lower when there are more pedestrians. These investigations also examined what variables lead to vehicles driving faster. Besides a small number of pedestrians, there is good road visibility, good perceptibility of pedestrian crossings and low traffic densities.

These results agree with Pfundt's data (1964); he also finds that the variable of seeing pedestrians and the variable of road-width influence motorists in deciding to stop at a zebra crossing.

The R.R.L. tells of research during which pedestrians were asked to say when they would cross the road in front of approaching vehicles; the "theoretical" accident rate then rises rapidly as from 60 km/h (Moore and Older, 1965). With increasing speed it becomes more and more difficult to estimate the time required for crossing. Observations have shown that the speed at which pedestrians cross increases when the interval of time is short.

Research in Switzerland also shows that vehicles travelling faster than 60 km/h do not stop to allow pedestrians to cross (schweizerische Beratungstelle für Unfallverhütung, 1965).

The Influence of Road-Width. When there is little wheeled traffic there are also few problems for pedestrians in crossing the road. As traffic gets busier they wait for a gap in the traffic. The average waiting time increases as traffic increases, as Smeed has calculated.

Smeed (1968) assumes that vehicles approach at random, pedestrians at a speed of 4.8 km an hour and that the vehicle flow is 183, 130 and 53 vehicles per meter road-width per hour. The corresponding speeds are 16, 24 and 32 km per hour.

In this way we can form an idea of the average times of waiting for a gap in the traffic through which a pedestrian can cross the road (Table 2).

Table 2
Average Waiting Time For Openings In
Random Traffic Flow Through Which
Pedestrians Can Cross
(BRON: SMEED, 1968)

Width of road	Speed of traffic		
	10 m.p.h. = ±16 km/h	15 m.p.h. = ±24 km/h	20 m.p.h. = ±32 km/h
	Waiting time (seconds)		
12 feet = ±3.66 m	0.8	0.5	0.2
24 feet = ±7.3 m	12	8	2
36 feet = ±11 m	150	50	10
48 feet = ±14.6 m	4,000	500	30
60 feet = ±18.3 m	20,000	10,000	125
72 feet = ±22 m	6,000,000	400,000	600

From these theoretical observations, one conclusion can certainly be drawn. The possibility of finding gaps in the traffic in order to cross the road is greatly lessened as the road becomes wider. For instance a road-width of about 7.3 meters, at a given

speed and density, gives an average waiting time more than ten times as great as for a road about .6 meters wide. With a road-width of over 9 meters Smeed (1968) thinks it necessary for proper safety to help pedestrians by providing a footbridge, a subway, a zebra crossing or a controlled crossing.

The Influence of Publicity and Campaigns. According to Wiener (1968) a pedestrian crossing campaign may be useful because it reduces the percentage of illegal crossings, but as his investigations show, the effect disappears immediately the campaign has ended unless effective supervision continues, for instance by a police officer. If a campaign is to be successful at any rate while it lasts, it must be short and intensive.

It is striking that a big percentage of older pedestrians is totally unimpressed by campaigns, legal sanctions or certain traffic regulations. Senility, fixed habits, unfamiliarity with traffic hazards and rules, or deliberate disregard make their behavior fixed and unresponsive to sanctions. Moreover, old people often think that the police, the local authorities and the town planners make hardly any allowance for them. Wiener asks for more use to be made of helpers (such as traffic guides) where there are high concentrations of old people.

Note: Traffic conditions should take old people into account, because this category (and also children) have specific characteristics differing greatly from those of other road-users.

An intensified pedestrian safety campaign was run for a week in Madrid (Jefetura 1964). It was concentrated on the road-crossing regulations for pedestrians. All available mass media were used: the press, TV, radio, posters, loudspeakers, pamphlets, strips along pavement edges. The effect of the campaign was measured by means of questionnaires and by before, during and after observations of pedestrian behavior. The percentage of pedestrians crossing correctly at light-controlled intersections was 41% before, 59% during and 59% after. At zebra crossings the percentages were 38%, 50% and 54% respectively. Where there were no traffic lights or markings, correct crossing was defined in terms of head movements before crossing over. The percentages in this case were 94%, 98% and 95% respectively. No changes were found in the accident pattern.

Note: It is not known whether there was a higher level of police enforcement during (or perhaps after) the campaign. Nor is it known what the long-term effect is.

Influence of Alcohol. Other factors affecting the safety of pedestrian behavior are drink and drugs.

While some investigations have studied the alcohol problem as a cause of pedestrian accidents, no studies are known in the literature on the effect of drugs on pedestrian behavior and safety. This is due mainly to the difficulty of detecting the presence of drugs in the body (Havard, Goldberg, 1966).

Both Gerber (1941) and Gonzales and Gottler (1941) found that a substantial percentage of a large number of pedestrians involved in accidents were under the influence of alcohol.

Gerber found that 37.3% of 314 pedestrians killed in traffic accidents had a blood alcohol concentration higher than 130 mg per 100 ml. Gonzales and Gottler found that 30.7% of 2472 pedestrians killed in traffic accidents had a brain or liver alcohol concentration higher than 20 mg and 26.2% of these were higher than 100 mg. Böhm (1966) found alcohol as a very frequent cause of accidents involving elderly pedestrians, especially even with BACs from 89 mg to 100 mg per 100 ml.

A study by Haddon et al. (1961) used a control group. He found that very fuddled pedestrians (higher than 130 mg/100 ml) were frequent in the test group. But even BACs of 10 to 40 mg/100 ml significantly increased the accident hazard.

The Influence of Education. The literature discloses nothing about the effect of tutorial systems at schools as a means of teaching children better road drill.

Literature exists on road drill with model traffic-training areas. Research by Sandels (1969), however, makes it clear that these facilities are not such an educational success for children between 7 and 9. The conclusion from Sandels' research is that this method is not much better than teaching no road drill at all. The best method was training under actual traffic conditions.

Observations. Systematic observations can compile knowledge of pedestrian behavior liable to cause accidents. This has been done by Wolff (1961). The most common form of wrong behavior in a German city is crossing intersections diagonally and crossing behind parked vehicles.

Possible Measures. Based on the data in this section, a number of measures can be proposed.

- In order to reduce material/pedestrian conflicts to a minimum, the measures will mainly have to relate to the pedestrian's obligations (see: Conclusions, page 38).

- There are indications that pedestrians can be encouraged to use crossings by means of good zebra markings.
- With high-density motor traffic where there are no longer any gaps in the traffic, there is no point in expecting pedestrians or motorists to adjust to one another. Zebra crossings are not, therefore, suitable under such conditions.
- To ensure more effective adaptation of pedestrian/motorist behavior, pedestrians could give a clear signal to approaching motorists when they are about to cross over a zebra. This rule already exists in Switzerland.
- As pedestrians crossing the road estimate the available time and, if vehicle speeds are faster, tend to accept shorter intervals, the risk increases on roads where speeds are high. It has also been found that vehicles travelling faster than 60 km/h do not stop to allow pedestrians to cross the road. This means that on roads where speeds exceed 60 km/h a zebra crossing does not adequately protect pedestrians; a controlled crossing or a footbridge or subway will be safer.
- SWOV research has shown that dimmed headlamps and side lights both have certain drawbacks. It is necessary to seek a lighting system for the front of motor vehicles without those drawbacks but with the advantages. This can be achieved with a light having an intensity between that of the present dimmed headlamps and side lights, so that the vehicle will be properly observed by the pedestrian while the degree of glare is acceptable.
- With roads wider than 9 meters it is advisable to help pedestrians to cross by providing for instance a traffic island, a zebra crossing, etc.
- Pedestrian safety campaigns work only if they are accompanied with a higher level of police enforcement; long-term effects cannot be expected. Helpers at dangerous spots and for certain categories of road-users (children and old people) are more promising.
- Alcohol apparently has much influence on pedestrian hazards. Good, selective law enforcement may improve this.
- Training with model traffic-training areas is not the best way. Children should be taught road sense with good training methods at school and under actual conditions; training areas may then form an addition to their education.

- In streets with vehicles parked along the pavement pedestrians could be protected by making crossings at intersections compulsory in short streets and providing zebra crossings in long streets.

Regulations

The regulations applicable to pedestrian and motorist behavior vary somewhat from country to country.

The regulations are specified most as regards behavior on and near zebra crossings. A compilation has therefore been made showing those regulations for the best European countries and the U.S.A., together with a United Nations proposal.

This compilation can be found in Kraay (1971): "Rules of Conduct for Pedestrians and Motorists on or near Zebra Crossings."

A general review and a number of national differences are given.

Possible Measures. Based on the foregoing review, a number of measures can be recommended with a view to achieving more uniform regulations.

- If some new regulations are taken, both the pedestrian and the driver must respect them; otherwise the efficiency will break down and (1) other existing measures will be disregarded (snowball effect) and (2) certain persons will behave according to the new measure, while others will not.
- Not all countries require motorists to approach zebra crossings at a moderate speed. As most countries do have this rule, it could be introduced in the others.
- Norway and Spain do not explicitly state in their legislation that motorists must stop for a pedestrian who is on the crossing. This is probably the intention, however, and this rule could be added in these countries.
- Nor is there any uniformity regarding vehicles overtaking before a zebra crossing. To avoid much misunderstanding and to minimize pedestrian/motorist conflicts, it is advisable to forbid overtaking just before a zebra crossing.
- It is also advisable to have a uniform regulation that vehicles must not park immediately before or after a zebra crossing. A distance of 10 meters seems feasible.
- The United Kingdom, Norway and Switzerland do not require pedestrians to use zebra crossings. This

requirement should be included so as to channel pedestrian movements better.

- The prohibition against pedestrians crossing the street within a given distance of a zebra crossing does not exist in all countries; where it does exist, the distance varies greatly. A recommendation to forbid pedestrians crossing within 30 meters of a zebra crossing seems feasible.
- It would also seem appropriate for all countries to have a rule that pedestrians using a zebra crossing must not disregard or endanger wheeled traffic.

Law Enforcement

Law enforcement can be described as the aggregation of activities aimed at modifying road-users' behavior to make traffic safe and efficient. A number of methods exist for enforcing the desirable behavior that is prescribed by law: warning, punishment and prevention.

The following does not go into the question of social compulsion among road-users themselves to ensure that the regulations are obeyed.

Criteria for Code of Conduct. Traffic regulations are mainly codes of conduct. If such codes are to meet their purpose of ensuring road safety they must satisfy the following requirements:

- They must provide information, i.e. be understandable, relate to a specifically defined situation or procedure, be capable of straightforward interpretation.
- They must have no inherent contradictions, i.e. obeying them must not clash with other codes.
- They must be valid, i.e. be significant for road safety, hence not superfluous or incomplete.
- They must be capable of being obeyed by road-users and of being enforced by the police. Such obedience may be either physically or psychologically enforceable. Psychologically, the individual road-user must not suffer too much discomfort.

If codes of conduct do not satisfy these criteria, they may cause problems among road-users, thereby making their legal position more uncertain and perhaps detracting from road safety.

Most countries' regulations on pedestrian and driver behavior on and near zebra crossings do not completely satisfy requirements above.

Example: If a pedestrian is to use his right to cross the road without obstruction he must already be on the zebra crossing (except in Switzerland). But he hardly dare set foot on the zebra as long as fairly high-speed traffic is approaching, and he stands waiting at the crossing. The traffic responds by

REGULATIONS APPLICABLE TO MOTORIST AND PEDESTRIAN BEHAVIOR

Motorists							Pedestrians		
Regulations	Approach Crossing at Moderate Speed	Stop for Pedestrians on Crossing	Overtaking Before Crossing yes no	No Stopping and/or Parking on Crossing	No Parking Before or After a Crossing	Use of Crossing Compulsory	No Crossing Over Within Given Distance	Wheeled Traffic not to be Endangered	
Belgium	x	x	x ¹	x	5 m before	x		x	
Denmark	x	x	x ¹	x		x		x	
Germany	x	x		x		x	50 m	x	
Great Britain	x	x	x	x	8.5 m after	x	14.5 m	x	
France		x	x ¹	x		x	100 m	x	
Ireland		x		x		x	50 m		
Italy		x		x		x	30 m	x	
Luxembourg	x	x		x	5 m before + after	x			
Netherlands	x	x		x	4 m + 50 m ³	x	25 m	x	
Norway						x			
Austria	x	x		x		x			
Portugal	x			x		x			
Spain				x		x			
USA					5.66 m before & after ²	x			
Sweden	x	x		x	10 m before	x	50 m	x	
Switzerland	x	x		x	10 m before	x		x	
United Nations	x	x	x ¹	x		x			

Source: Kraag (1971)

- 1) If no pedestrians on crossing
 - 2) When pedestrian crossing is near an intersection
 - 3) In built-up areas 4 metres before and after
- Outside built-up areas 50 metres before and after

driving on without slowing down. In this way the zebra crossing is of little benefit to the pedestrian. Nor is there much point in taking a step on to the crossing and standing there, because the motorist still interprets this as "waiting." The customary practice now is:

- a pedestrian only steps on to a zebra crossing when approaching vehicles are still fairly far away;
- if a line of cars is passing, the pedestrian waits until they have gone;
- the motorist approaches at a normal speed and does not apply his brakes until one or more pedestrians are crossing and a slight swerve no longer suffices to avoid the pedestrian or pedestrians.

Behavior differing from the above sometimes occurs, but is usually not quickly understood and causes dangerous situations; for instance:

- the pedestrian who crosses over just in front of an approaching car so that the motorist has to apply his brakes harder;
- the motorist who slows down and/or stops while the pedestrian is still standing on the pavement or on the beginning of the zebra crossing (liable to cause head/tail collisions).

Accidents caused in this way generally have little to do with seeing too late or not at all, but tend to be due to misunderstanding between pedestrians and drivers or between different drivers.

The situation becomes more complicated in the following cases, which may involve misunderstanding and also seeing too late or not at all:

- a car stops; the next car drives on, past the first one. The pedestrian encouraged to continue crossing by the first car having stopped, now runs an extra risk;
- a car stops, the pedestrian continues crossing and forgets to watch out for vehicles from the opposite direction;
- a car stops, a following car sees this too late or is too close behind and runs into the first car. If the first car is pushed on to the zebra crossing, the pedestrians on it are also in danger.

For the first case, most countries have a regulation that drivers must not overtake vehicles standing before a zebra crossing; but they still do so.

As regards enforcement, the police are usually unable to apply adequate sanctions against traffic offenses by pedestrians. In particular, little attention is paid to regulations concerning pedestrian behavior on and near zebra crossings, probably because the police are understaffed.

The rules which the authorities have formulated to minimize conflicting situations between motorists and pedestrians on and near zebra crossings are far from the optimum. Consequently, they will not have the maximum effect on safety.

Folk Crimes. Laws are made, as stated earlier, to modify human behavior. If a minority of road-users infringe the road-traffic regulations this is a form of deviant behavior.

But if the majority of road-users infringe one or more road-traffic regulations, the offense is a folk crime. The regulation is not taken seriously and a new standard of conduct is created. Once this new standard has assumed permanent, clearly defined forms, it will be difficult to apply sanctions that will restore the behavior which the law originally contemplated. Road-users do not take the regulation seriously and if the police summon them they look on this as bad luck. There is a strong impression that many traffic regulations in fact come within the category of folk crimes, making law enforcement difficult.

There are two important things that cause offenses to be looked upon as folk crimes and strengthen this idea:

- the objective and subjective risk of being caught;
- an aversion on the part of the police officer to summoning pedestrians, and police law enforcement policy.

As a rule, pedestrians have had little or no experience of punishment, and therefore hardly know of the objective risk of being caught, which is probably very slight. For them, therefore, their own interpretation plays a much bigger part.

On analysis, the risk of sanctions for the individual road-user proves to consist of:

- the risk of being apprehended while committing a traffic offense;
- the risk of prosecution after apprehension;
- the risk of a sentence after prosecution.

If these factors have a very low subjective rating, a measure aimed at changing the objective facts will have more effect on subjective evaluation until the optimum situation is reached. At the same time, assessment of the punishment after prosecution plays a part in creating the overall effect. The overall effect, expressed as pedestrian behavior, is a fairly complex product of these four subjective assessments. This means that if one of these subjective ratings is zero the product will be about zero too.

Sociological research has shown that the police have an aversion against summoning their equals.

That is to say, they feel they are fellow-sufferers with those who, like the policeman on patrol duty, are also pedestrians; this applies particularly to persons of the same social class as theirs. Policemen are mainly of lower middle-class origin (Bebbington, 1967; Cain, 1968, Nordhoit and Valkenburch, 1970).

This can be illustrated to some extent with, e.g., figures from the city of Haarlem (150,000 inhabitants). In 1967 the police summoned a total of 27,800 persons, only nine of whom were pedestrian; in 1968 out of a total of 33,447, there were 235 pedestrians, but it should be noted that in that year a pedestrian campaign was held in which the police collaborated "intensively." The figures for the years after were 1969 with 44,123 summonses including 75 pedestrians; 1970 with 41,877 including 72 pedestrians and 1971 with about 50,000 and about 28 pedestrians.

Besides police aversion against summoning pedestrian offenders, law enforcement policy obviously seems to fail in the case of pedestrians.

Conclusions. As long as the objective and subjective risks of being caught are not increased and police policy toward pedestrian offenders does not change, most pedestrian offenses will remain in the category of folk crimes. An improvement in pedestrian safety must not therefore be expected from short campaigns, because they hardly increase the objective risk of being caught, while the subjective risk is not changed.

Interpretation. A number of investigations into speed limits are shown which claim that an increased level of policy enforcement influences road-users' behavior positively and consequently leads to greater safety. Kraay and Mattie (1971) show that the scientific value of these investigations is debatable. The validity and reliability of the data and their statistical processing leave much to be desired, to say the least. The most common errors in the investigations are:

- failing to allow for regression of the accident curve after a high peak due to incidental factors;
- if a trend is allowed for in the accident pattern, it is justified to assume that in the research period (often short) the same trend exists as for a longer period; this is usually not taken into account;
- the samples are often too small;
- the non-inclusion of control situations in the research;
- the great deal of publicity, which may influence road-users' behavior in the research period, with consequent distortion of the results.

The O.E.C.D. Report on Enforcement (O.E.C.D., 1971) expresses the same reserve about many research results.

This means that research results should be treated with caution, especially as regards pedestrian safety, particularly as the numbers of pedestrian accidents in the relevant investigations are usually very small.

Research on Law Enforcement. As a rule, it is statistically easier to establish the effect of law enforcement on pedestrian behavior than on safety.

Hurford (1970) reviews the work done by the Metropolitan Police Traffic and Accident Research Branch into the effect of law enforcement on pedestrian behavior on and near zebra crossings. Table 2 shows that if there are automatic traffic signals pedestrians fail to carry out their normal curb drill and put their faith in the police officer.

Smeed (1968) says in this connection that the effect of the police presence on road-users' behavior agrees with the results of other research. For instance, an experiment in Slough (Ministry of Transport and Civil Aviation, 1957), where a police officer stood near a zebra crossing for certain periods, shows that the number of motorists giving way to pedestrians was 25% higher than if there was no police officer present. The number of adult male pedestrians using the zebra crossing showed a significant increase.

Note: This study in Slough was of very brief duration.

A study on this subject by Wiener (1968) shows that during a law enforcement campaign directed at pedestrians there was a very big increase in legal crossing. But four months after the intensified enforcement the percentage of illegal crossings was just as high as before the campaign.

Possible Measures. On the basis of the very scanty research, the following recommendations can be made.

- Generally speaking, there is little law enforcement as regards pedestrian offenses. Stricter enforcement by the police might ultimately have a long-term preventive effect for pedestrian safety.
- The mere presence of police near zebra crossings makes more people use them. This information could be put to greater use in enforcement methods.
- Law enforcement campaigns only have a short-term effect because the objective risk of being caught is increased for only a short time. Owing to the police being understaffed (due to which the objective risk of being caught can hardly be increased) it might be advisable to take steps to

increase the subjective risk so that the same desired pedestrian behavior can be achieved (for example by selective enforcement).

FRAMEWORK FOR FUTURE MEASURES

The conclusions from the SWOV paper in which a number of measures relating to pedestrian safety have been enumerated, state that (apart from segregating different kinds of traffic) these measures hardly have any positive effect on pedestrian safety.

We are also convinced that a number of measures have been introduced based on ideas, hypotheses or theories, without these having been scientifically investigated.

One should not be a priori opposed to this, but in such a procedure ideas, hypotheses and theories should form part of a wider analytical approach.

In endeavoring to influence road safety in a positive sense, we would like to go into two aspects which are of importance in studying the problem:

- a more fundamental approach to these problems in contrast to incidental measures based on disconnected ideas,
- the behavioral rules for pedestrians and automobilists on and near zebra crossings.

In very many cases it will be impossible to avoid potential conflicts between pedestrians and vehicles.* In cases where potential conflicts occur, traffic conditions should have as little variety as possible. Less variety will make occurrences more predictable and there will be a bigger chance of getting information across to pedestrians and motorists regarding such occurrences. This means that the task of road users will become easier and potential conflicts will therefore emerge less often.

To limit obvious conflicts between vehicles and pedestrians, two principles can be adopted, based on the foregoing:

- make the movements of pedestrians and vehicles homogeneous at places where these types of traffic intersect at the same level;
- make traffic conditions uniform where the routes of pedestrians and vehicles intersect at the same level.

These two principles are closely related.

I. The pattern of pedestrian movement can be made homogeneous as follows:

- by making pedestrian crossings always at the same points in comparable traffic conditions or at places where pedestrians normally cross the road;
- by restricting the possibilities of crossing the road except at pedestrian crossings;
- by getting pedestrians to cross in groups instead of making individual decisions to cross over;
- by making an x number of pedestrian crossings per kilometer of road, per area of land, per number of intersections, etc.;
- by having rules for crossing the road at pedestrian crossings and at other places.

The movement pattern of motorists can be made homogeneous as follows:

- by making pedestrian crossings always at the same places in comparable traffic conditions, or at places where pedestrians normally cross the road, or at places where motorists expect pedestrians to cross;
- by making an x number of pedestrian crossings per kilometer of road, per number of intersections, etc.;
- by having rules for approaching pedestrian crossings.

II. For making the traffic situations uniform, the very first thing is to choose between similarity in perceptibility of the situation and uniformity in its conception.

- Similarity in perceptibility of pedestrian crossings and the pedestrians on them can be achieved with:
 - a. conspicuousness of the pedestrian crossing and any (prior) warnings;
 - b. recognizability of the pedestrian crossing and any (prior) warnings;
 - c. expectation of the presence of a pedestrian crossing.
- Uniformity in conception can be achieved with:
 - a. uniform lighting;
 - b. uniform marking;
 - c. uniform (prior) indication.

The above items concern the motorist; they will play no significant part for pedestrians (except in expectation of the crossing's presence as regards perceptibility).

Based on the principles of homogeneity and uniformity, the homogeneity of pedestrian movements in the case of zebra crossings can be promoted, for instance, by the location of the crossings, their number, restrictions on crossing elsewhere than at the zebra crossing in groups instead of individually, rules; homogeneity in vehicle movements can be promoted, for instance, by the location of zebra crossings, their number, rules.

*Further observations will be concerned only with motorists, motor cyclists, scooter riders and cyclists will be disregarded.

ANALYSIS OF THE PROBLEM OF PEDESTRIAN SAFETY

Principles to diminish conflicts between motorists and pedestrians	homogeneity	pedestrians		1. location of ped. crossing 2. number of ped. crossings 3. restrictions to cross elsewhere 4. to cross in groups 5. behavioral rules
		motorists		1. location of ped. crossing 2. number of ped. crossings 3. behavioral rules
	uniformity	perceptibility of ped. crossing	pedestrians	1. expectation of the presence of ped. crossings
			motorists	1. conspicuousness of ped. crossings 2. recognizability of ped. crossings 3. expectation of the presence of ped. crossings
		uniformity in the conception of ped. crossings	pedestrians	
			motorists	1. lighting of ped. crossings 2. marking 3. (prior) indication

On the whole one may say that if those rules are to meet their purpose of safe traffic regulation, they must satisfy the following requirements:

- They must be informative, i.e., be intelligible, relate to concretely defined situations or behavior, be capable of only one interpretation.
- They must involve no contradictions, i.e., compliance with them must not conflict with other rules.
- They must have validity, i.e., be significant to safe traffic regulation, and not be superfluous or incomplete.
- It must be possible for the road user to obey them and for the police to enforce them. Obedience may be both psychological and physical. In its psychological form, the road user must not be inconvenienced too much.

If rules do not meet these criteria, they may cause problems for road-users and make them uncertain of their legal position, and perhaps be detrimental to road safety.

To Sum Up: The conclusion of the foregoing is that if pedestrian safety regulations are to have positive

results, they will have to form part of a scientific approach to the problems. More analytical work will have to be done before appropriate regulations can be formulated.

LITERATURE

- A.A.A. (American Automobile Association). Manual on pedestrian safety, Washington, D.C., 1964.
- Bebbington, B. N. Police and human relations, British Congress on Crime, 1966, *Excerpta Criminologica*, 1967.
- Böhm, H. Alte Menschen als Fußgänger im Strassenverkehr. Bundesverkehrswacht, Bonn, 1966.
- Cain, M. E. Role conflict among police juvenile liaison offices. *British Journal of Criminology*, 1968, pp. 366-382.
- Cohen, J.; Dearnaly, E. J. & Hansel, C. E. M. The risk taken in crossing a road. *Operations Research Quarterly* 6 (1955) 3:120-127.
- Gerber, S. R. Cuyahoga County Coroner's Statistical Survey. Cleveland, Ohio, 1941.

- Giovanelli, R. G., Blevin, W. R. & Wright, K. A. Floodlighting of pedestrian crossings. *Trans. Illum. Engineering Soc.* 27 (1962) 3:139-142.
- Haddon, W., Vallen, P., McCarroll, J. R., Umberger, Ch.G. A controlled investigation of the characteristics of adult pedestrians fatally injured by motor vehicles in Manhattan. *Journal of Chronic Diseases*. St. Louis. Vol. 14 no. 6, pp. 655-678, 1961.
- Hakkesteegt, P. Flexibel verkeerslichtensysteem in Delft. *Verkeerstechniek*, 21 (1970) 9:483-493.
- Havend, J. D. J., Goldberg, L. On the effect of alcohol and drugs on driver behavior and their importance on a cause of road accident, O.E.C.D., Paris, 1966.
- Herwig, B. Untersuchungen über das Verhalten von Kraftfahrern und Fußgängern an Zebrastreifen. In: *Forschungsbericht der Technischen Hochschule*. Braunschweig, 1965.
- Herwig, B. Verhalten von Kraftfahrern und Fußgängern an Zebrastreifen. *Zeitschrift für Verkehrssicherheit* 11 (1965) 4 : 189-202.
- Hurford, R. The effects of police presence on road user behavior, London Metropolitan Police, 1970.
- Jacobs, D. The effect of zebra crossing installations on pedestrians and vehicles; No. 1 : Viewaly High Street. *The Surveyor and Municipal Engineer* 126 (1965) 3816: 23-27.
- Jefetura Central de Trafico. The pedestrian walk, *International Police Chronicle*, Madrid, 1964.
- Kraay, J. H.; Mattie, P. Snelheidsbepalingen en politietoezicht. *Delikt en Delinkwent*, afl. 7, mei 1971.
- Kraay, J. H. Rules of Conduct for Pedestrians and Motorists on or near zebra crossings. Institute for Road Safety Research SWOV, Voorburg, the Netherlands, 1971.
- Mackie, A. M. Accident risk to pedestrians on and within 50 yards of zebra crossings. *Traff. Engng. & Control* 4 (1962) 8: 448-450.
- Ministry of Transport. The Slough experiment, report on large scale experiment into effectiveness of road safety measures conducted in Borough of Slough from April 1955 to 1957.
- Moore, R. L. Psychological factors of importance in traffic engineering. Inc., *Proc. International Study Week in Traffic Engineering*, Stresa 1956, Theme III: Psychology and education of road users. O.T.A., London, 1956.
- Moore, R. L. & Older, S. J. Pedestrians and motor vehicles are compatible in today's world. *Traff. Engng.* 35 (1965) 12: 20-23 and 52-58.
- Nederlandse Stichting voor Verlichtingskunde, Aanbevelingen voor de verlichting van voetgangersoversteekplaatsen, *Verkeerstechniek* 18 (1967) 7: 306-307.
- Nordholt, E. E., Valkenburgh, P., Enige aspecten van de verhouding burgerij-politie, *Verslag van een Gronings onderzoek*, Alphen aan de Rijn, 1970.
- Organization for Economic Cooperation and Development OECD, The effects of the enforcement of legislation on road user behavior and traffic accidents, Parijs, 1972 (nog vertrouwelijk).
- Pfundt, K. Zur Frage des Angabe von Kriterien und Einsatzgrenzen für Fußgängerüberwege. In: *Mitteilungen des Beraters für Schadenverhütung* No. 4 Köln, Huk-Verband, 1964.
- Robinson, C. C. Pedestrian interval acceptance. In: *Proc. Institute of Traffic Engineers* 1951. Washington, 1951.
- R. R. L. (Road Research Laboratory). Research on road traffic. Ch. 12: Pedestrians. H.M.S.O., London, 1965.
- Sandels, S., Children in traffic, *Lezing gehouden op de jaarvergadering van het N.V.B.V.*, Den Haag, 1969.
- Schreuder, D. A. Marking and lighting of pedestrian crossings. *Intern. Lighting Rev.* 15 (1964) 2: 75-77.
- Sharfuddin, F. Some minor change improve pedestrian safety. *Transp. Commun. Mon. Rev.*, 1959, pp. 12-18.
- Smeed, R. J. Some aspects on pedestrian safety. *Journ. of Transport Economics and Policy* 2 (1968) 3.
- SWOV, Side light and low-beam headlights in built-up areas, Voorburg, 1969.
- Utter, R. F. The influence of painted crosswalks on the behavior of pedestrians and automobile drivers. Institute of transportation and traffic engineering, University of California, 1949.
- Wepf, K. W. Das Verhalten von Fußgängern und Fahrzeugführern und Fußgängerstreifen. *Strassenverkehrstechnik*, Heft 5/6, 1966.
- Wiener, E. L. The elderly pedestrian; Response to an enforcement campaign. *Traff. Safety Research Rev.* 12 (1968) 4 : 100-110.

Rules Of Conduct For Pedestrians And Motorists On Or Near Zebra Crossings

AUSTRIA

Bundgesetzblatt 1960, issued 30th July 1960
Federal Act: Strassenverkehrsordnung 1960 - StVO, 1960

Section 9, para. 2 The driver of a vehicle must approach a pedestrian crossing only at such a speed that the vehicle can be halted before the crossing to enable a pedestrian on the crossing to cross without hindrance or danger.

Section 16, para. 1(d) The driver of a vehicle must not overtake: on pedestrian crossings or, if there is a line marked across the carriageway, within this marking.

Section 17, para. 3 It is forbidden to drive past pedestrian crossings which are marked to allow pedestrians to cross the road.

Section 24, para. 1(c) Halting and parking is prohibited: (c) on pedestrian crossings.

Section 76, para. 4 At places where traffic is not regulated either by hand-signals or by lights:

(a) if pedestrian crossings exist in conjunction with a cross-line, pedestrians must no longer walk onto the crossing if an approaching vehicle has already reached such line;

(b) if pedestrian crossings exist without a cross-line but in conjunction with a flashing yellow light or else at an intersection (Sec. 56, para. 3(b)), pedestrians must not step onto the crossing directly in front of an approaching vehicle unexpectedly to the driver.

Section 76, para. 6 If pedestrian crossings or footbridges or subways exist, pedestrians must use these facilities. If, however, none of these facilities are provided or are more than 25 meters away, pedestrians in the district must cross the road only at intersections, unless traffic conditions undoubtedly allow the carriageway to be crossed safely at other places as well.

BELGIUM

Royal Decree containing general regulations on policing of road traffic, 14th March 1968

Article 26 4. At places where the traffic is not controlled by a qualified person or by traffic lights,

but where there is a pedestrian crossing, a driver must only approach this at a moderate speed in order not to endanger pedestrians who are on it and not to inconvenience them if they complete their crossing of the carriageway at a normal pace. If necessary he must stop to let them continue.

5. A vehicle approaching or stopping before a pedestrian crossing may only be overtaken at such a moderate speed that the driver can stop for a pedestrian who is on the crossing and whom he could not have observed.

6. Subject to clauses 3 and 4 of the present article, a driver changing direction must not endanger pedestrians crossing the carriageway on which he is going to travel.

7. A driver must not drive onto a pedestrian crossing if the traffic in the direction he is going is blocked to such an extent that he is likely to be held up on that spot.

Article 48 3. Crossing the carriageway:

1. If there is a pedestrian crossing close by, pedestrians must use it.

4. At places where traffic is not controlled either by a qualified person or by traffic lights, but where there is a pedestrian crossing, pedestrians must only step onto the crossing carefully while observing the distance of the approaching vehicles, even if the crossing is marked with the flashing yellow beacons as provided by Article 107.2.

DENMARK

Danish Road Traffic Act of May 24, 1965, promulgated with amendments June 27, 1961

Section 36 Speed 2. In particular, it is the driver's duty to travel at a speed low enough in view of the circumstances:

(j) before a pedestrian crossing.

Section 37 Right of way 5. If there are pedestrians on a pedestrian crossing, drivers must slow down, and if necessary stop, to allow pedestrians to cross.

Section: Stopping and parking 3. Stopping and parking is forbidden:

(d) on a pedestrian crossing or such a distance before a pedestrian crossing that the view is thereby diminished.

Section: The following rules apply to pedestrians walking along roads: 2. The following rules apply for crossing a carriageway or a cycle path:

(a) If there is a special pedestrian crossing nearby, it must be used if there is wheeled traffic of any significance.

(d) Passengers must cross over, also on a pedestrian crossing, as quickly as circumstances permit. When crossing over away from a pedestrian crossing they must take special care as regards wheeled traffic.

GERMANY

Strassenverkehrsordnung — StVO — 18th November 1970

Section 12 Halting and Parking (1) Halting is not allowed.

4. On pedestrian crossings or up to 5 meters before them.

Section 25 Pedestrians (3) Pedestrians must cross carriageways quickly by the shortest route at right angles to the traffic and with due regard to the wheeled traffic and, if the traffic situation so requires, only at intersections or junctions, inside the markings at traffic lights or on pedestrian crossings (Sign 293).

If the carriageway is crossed at intersections or junctions, the pedestrian crossing or markings at traffic lights must always be used.

Section 26 Pedestrian crossings (1) At pedestrian crossings, vehicles, with exception of rail vehicles, must allow pedestrians wishing to cross the carriageway by the pedestrian crossing to cross over. They must therefore only approach at a moderate speed; if necessary they must wait.

(2) If traffic is held up, vehicles must not travel onto the crossing if they would have to wait on it.

(3) Other vehicles must only be overtaken or passed on crossings if it can be perceived that there is not danger to pedestrians. If a vehicle is waiting before a crossing because pedestrians are crossing the carriageway, other vehicles must not overtake it.

(4) If the markings cross a cycle path or another path of the road, these regulations apply *mutatis mutandis*.

ENGLAND

Road Traffic Act, 1960, London, 1968

46. (1) The appropriate Minister may make regulations with respect to the precedence of vehicles

and foot passengers respectively, and generally with respect to the movement of traffic (including foot passengers), at and in the vicinity of crossings.

(2) Without prejudice to the generality of the foregoing subsection, regulations made thereunder may be made prohibiting foot passenger traffic on the carriageway within one hundred yards of a crossing, and with respect to the indication of the limits of a crossing, or of any other matter whatsoever relating to the crossing, by marks or devices on or near the roadway or otherwise, and generally with respect to the erection of traffic signs in connection with a crossing.

The Highway Code, Ministry of Transport, London, 1968

Zebra crossings 13. You have no priority at a zebra crossing until you have stepped on it, but, when you do, traffic must give way to you. Always allow vehicles plenty of time to slow down or stop before you start to cross, especially if the road is wet or icy.

14. Although drivers must give way to you once you are on the crossing, look right and left as you cross, even if one driver has given way, another might not have seen you, or might try to overtake.

15. If there is an island in the middle of the zebra crossing, use each half of the road as a separate crossing.

42. When coming to a zebra crossing, be ready to slow down or stop to let people cross. You must give way once they have stopped on to a crossing. Signal to other drivers that you mean to slow down or stop. Give yourself more time to slow down or stop on wet or icy roads.

43. Never overtake just before a zebra crossing.

44. In traffic queues, leave zebra crossings clear.

47. When turning at a road junction, give way to pedestrians who are crossing.

FRANCE

Code de la Route, Journal Officiel de la Republique Francaise, 8th February 1969

Article R. 219 Pedestrians must only cross the road after having satisfied themselves that they can do so without immediate danger, taking into account especially the visibility and the distance and speed of vehicles.

Where pedestrian crossings exist within 50 meters, they must use these. At intersections near to which there is no pedestrian crossing, pedestrians must take the part of the road in line with the pavement.

Article R. 219-2 Pedestrians must keep off the road at a square or intersection unless a pedestrian crossing allows them to cross straight over. They must walk round the square or intersection, crossing as many as may be necessary.

Article R. 220 Drivers must allow pedestrians to cross in the conditions envisaged in Articles R. 219 to R. 219-3. They must take every step to this effect. This applies particularly when vehicles coming from another road turn to enter the road on which there is a pedestrian crossing.

Article R. 220-1 On approaching pedestrian crossings drivers must not overtake without having satisfied themselves that there are no pedestrians on the crossing.

Article R. 220-2 All drivers are forbidden to halt or park wrongfully on a pedestrian crossing.

IRELAND

Statutory Instruments, S. J. No. 294 of 1964. Road Traffic General Bylaws. Dublin, 1964

Article 22 (9) A driver approaching a zebra crossing shall yield the right of way to a pedestrian on the crossing.

Article 26 (1) When parking, a driver shall ensure that the vehicle:

(d) will not be wholly or partly on a zebra crossing or within thirty feet of a zebra crossing or pedestrian lights; provided that the restrictions on parking imposed by this subparagraph shall, in a street where traffic is permitted to travel in either direction, apply only to the side of the street on which traffic approaching the zebra crossing or pedestrian lights is required to travel, and in a one-way street shall apply only to that side of the crossing or lights from which traffic is required to approach the crossing or lights.

Article 38 (1) On a roadway on which a zebra crossing has been provided a pedestrian shall not cross the roadway within 50 feet of the crossing except by the crossing.

(2) When a vehicle is approaching a zebra crossing a pedestrian shall not step onto that crossing if his action is likely to cause the driver either to brake suddenly or to swerve.

LUXEMBOURG

Road Traffic Legislation. Code de la Route, April 1971

Article 123 At crossings, forks and junctions where traffic is regulated by traffic police or by

lighted or unlighted colored signals, drivers changing direction must not inconvenience traffic coming from the opposite direction or drive onto a pedestrian crossing so as to obstruct pedestrians who are crossing the road during the time the traffic is moving in the same direction or who are completing their journey over a crossing which they have already commenced at that time.

Article 125 A driver may only overtake vehicles approaching a pedestrian crossing or stopping directly at it at a pace sufficiently reduced to be able to stop on the spot if a pedestrian is on the crossing.

Article 138 When a line of vehicles is stopped at a crossing, a fork or a junction, drivers must not halt their vehicles in a manner obstructing the passage of other drivers travelling on the intersecting road. Furthermore if a line of vehicles is stopped near a level crossing or a pedestrian crossing, drivers must not halt their vehicles on such crossings.

Article 142 On zebra crossings whether indicated ahead or not with the sign provided for in para. 18 of Article 107 above, or marked directly with a flashing yellow light, drivers must only approach at a moderate speed so as not to endanger pedestrians there or inconvenience them in continuing their normal journey. If necessary, drivers must stop to allow the pedestrians to go on.

Article 162 Pedestrians must observe the following rules:

7. At places where pedestrian crossings are provided they must not cross the road outside such crossings, unless they are more than 50 meters away from such a crossing.

10. On pedestrian crossings not bearing the two or three-colored markings or where traffic is not regulated by a traffic policeman, they may only go on to the crossing carefully and taking into account the distance and speed of approaching vehicles.

Article 164 It is forbidden to halt a vehicle or an animal:

(c) on pedestrian crossings and cycle crossings.

Article 166 It is forbidden to park or leave vehicles or animals:

6. on pedestrian crossings and cycle crossings.

THE NETHERLANDS

Traffic Rules and Symbols Regulations. Royal Decree 4th May 1966. Stb. 181

Article 37 3. Overtaking on the left or the right is forbidden if the vehicle being overtaken is stationary before a zebra crossing or is approaching it slowly.

Article 79 If the traffic has to stop, drivers must not obstruct the part of the road intended for traffic from the opposite direction, pedestrian crossings or cycle crossings, and must leave a passage open for intersecting traffic at crossings and junctions.

Article 81 2. It is forbidden in any event to halt a vehicle:

(b) on pedestrian crossings and cycle crossings;

(g) within a distance of 5 meters before pedestrian crossings and cycle crossings and, if there is a "no-stopping" sign on the right side, within 5 meters after it; this regulation does not apply to two-wheeled motor vehicles.

Article 99 2. Pedestrians must not cross the road within 30 meters of a zebra crossing.

3. The rule in 2 does not apply if the pedestrian would first have to cross another road in order to reach such pedestrian crossing, nor if he walks to or from a public transport vehicle from or to the nearest footpath or pavement.

Article 100 1. Drivers must approach zebra crossings with care and must give free passage to pedestrians who are on the crossing.

2. This obligation does not apply to police cars or fire engines, ambulances or motor vehicles or other emergency services designated by the Minister of Transport and carrying visible and audible signals as directed by the Minister under Article 58, nor to military convoys or funeral processions.

NORWAY

Trafikkregler, am 12. juni 1965

Section 17. Stopping, parking, etc. 4. It is forbidden to stop or park on any account:

(e) on a marked pedestrian crossing, or closer to the crossing than 4 meters inside built-up areas, or within 50 meters outside built-up areas.

PORTUGAL

Código da Estrada, e seu regulamento; Loures, dezembro de 1970

Section II, Article 7 2. The speed must especially be reduced in the following cases:

(h) At indicated pedestrian crossings.

Article 14 3. In built-up areas it is forbidden to halt or park:

(b) On pedestrian crossings indicated on the carriageway.

Section III, Article 40 3. When crossing any public road pedestrians must make sure that they can do so

without danger and they must cross at right angles. At squares or markets they must make use of indicated crossings, if available. The use of crossings at other places of public roads must be made in conformity with the municipal regulations contained in the respective regulations.

SPAIN

Código de la circulación: Edición cerrada el 10 de enero de 1970

Section III, Para. 67 If traffic is dense, the competent authorities must indicate the crossings for pedestrians, and pedestrians are prohibited from crossing the road at other places.

In streets where there are no pedestrian crossings, pedestrians must cross over at the end of a block of houses.

Section VI, Re Urban Traffic, Para. 111. Pedestrians. On roads where there are many people, pedestrian crossings must be clearly indicated, and pedestrians may cross over there only when the signals are given for traffic to stop.

SWEDEN

Vägtrafikförfattningar n.m.; 1 Vägtrafikförordningen, Vägtrafikförordning 28 Sept. 1951 (n. 648)

Note. The regulation was introduced by Royal Decree of 3rd June 1965 (No. 390).

Section 48 Drivers of vehicles must keep to a speed that is low enough having regard to the circumstances, when the vehicle approaches a crossing. Drivers must give way to pedestrians crossing a carriageway or on the point of crossing a carriageway at a controlled crossing in conformity with the directions of a traffic signal or a police constable. Drivers must stop to allow pedestrians to cross over an uncontrolled crossing if this is necessary to avoid danger or inconvenience to the pedestrian.

Section, Stopping and Parking. 2. Vehicles must not stop or park on the road without traffic conditions giving cause therefor:

(e) on pedestrian crossings or within a distance of 10 meters before a crossing.

Section 60 1. Pedestrians are obliged, where this is required to avoid danger or inconvenience to other traffic, to observe the following:

Pedestrians intending to cross carriageway must use crossings if these exist nearby.

SWITZERLAND

Bundesgesetz über den Straßenverkehr (19th December 1958) (As at 1st November 1969)¹

Article 33 1. Pedestrians must be able to cross the road in a proper manner.

2. Before zebra crossings drivers must drive with special care and halt if necessary to give precedence to pedestrians who are already on the crossing or are about to step onto it.

Article 40 2. Pedestrians must cross the road carefully and in the shortest way, if possible, on a zebra crossing. They have precedence on such a crossing but must not step on to it unexpectedly.

Ordonnance sur les règles de la circulation routière (13th November 1962).

Article 6 (Art. 33 LCR) 1. Before pedestrian crossings where the traffic is not regulated, drivers must reduce speed early enough to give precedence to pedestrians, especially those giving a hand-signal. They must give precedence to all pedestrians walking on the crossing in front of the vehicle.

Article 12 (Arts. 34, para. 4; 37, para. 1, LCR) 3. When the traffic is stopped, drivers must not halt on a pedestrian crossing, at an intersection, or block the path of crossing vehicles.

Article 18 (Art. 37, para. 2, LCR) 2. It is forbidden to halt intentionally¹

(e) On pedestrian crossings and less than 10 meters before them.

Article 19 (Art. 37, para. 2, LCR) 2. It is forbidden to park:

(a) Anywhere halting is not allowed.²

Article 47 (Art. 49, para. 2, LCR) 1. Pedestrians must step onto the road cautiously, especially if they are close to a halted vehicle, and must cross the road without loitering. They must use pedestrian crossings and also footbridges or subways provided less than 50 meters away.

2. On pedestrian crossings where there is no traffic control, pedestrians take precedence except over trams and road railways. Where a refuge cuts a pedestrian crossing in two parts, each of these must be regarded as a separate crossing.

3. Pedestrians wishing to use their right of way must announce their intention to the driver of an approaching vehicle by placing one foot on the road and giving a clear hand-signal. They must not use

their right-of-way when the vehicle cannot stop in time.

4. When traffic is dense, pedestrians must cross the road on the right-hand part of the crossing and if possible in groups.

UNITED STATES

Uniform Vehicle Code: Rules of the Road with Statutory Annotations, Washington, 1967

Par. 11-502 — Pedestrians' Right-of-Way in Crosswalks (a) When traffic-control signals are not in place or not in operation the driver of a vehicle shall yield the right of way, slowing down or stopping if need be to so yield, to a pedestrian crossing the roadway within a cross walk when the pedestrian is upon the half of the roadway upon which the vehicle is travelling, or when the pedestrian is approaching so closely from the opposite half of the roadway as to be in danger.

(c) Paragraph (a) shall not apply under the conditions stated in section 11-503 (b).

(d) Whenever any vehicle is stopped at a marked crosswalk or at any unmarked crosswalk at an intersection to permit to cross the roadway, the driver of any other vehicle approaching from the rear shall not overtake and pass such stopped vehicle.

Par. 11-503 — Crossing at Other Than Crosswalks

(a) Every pedestrian crossing a roadway at any point other than within a marked crosswalk or within an unmarked crosswalk at an intersection shall yield the right of way to all vehicles upon the roadway.

(b) Any pedestrian crossing a roadway at a point where a pedestrian tunnel or overhead pedestrian crossing has been provided shall yield the right of way to all vehicles upon the roadway.

(c) Between adjacent intersections at which traffic-control signals are in operation pedestrians shall not cross at any except in a marked crosswalk.

Par. 11-505 — Pedestrians to Use Right Half of Crosswalks Pedestrians shall move, whenever practicable, upon the right half of crosswalks.

Par. 11-1003 — Stopping, Standing or Parking Prohibited in Specified Places (a) Except when necessary to avoid conflict with other traffic, or in compliance with law or the directions of a police officer or official traffic control device, no person shall:

1. Stop, stand or park a vehicle:

d. On a crosswalk;

2. Stand or park a vehicle, whether occupied or not, except momentarily to pick up or discharge a passenger or passengers;

¹As regards halting close to tramways or road railway see also Art. 25, para. 5, as regards in tunnels, see Art. 39, para. 3.

²See Art. 18.

c. Within 20 feet of a crosswalk at an intersection.

UNITED NATIONS CONFERENCE ON ROAD TRAFFIC, VIENNA, 1968

Article 11 Overtaking and movement of traffic in lines 9. A vehicle shall not overtake another vehicle which is approaching a pedestrian crossing marked on the carriageway or sign-posted as such, or which is stopped immediately before the crossing, otherwise than at a speed low enough to enable it to stop immediately if a pedestrian is on the crossing. Nothing in this paragraph shall be construed as preventing Contracting Parties or subdivisions thereof from prohibiting overtaking within a prescribed distance from a pedestrian crossing, or from imposing stricter requirements on a driver of a vehicle proposing to overtake another vehicle stopped immediately before such a crossing.

Article 20 Rules applicable to pedestrians 6. (a) Pedestrians wishing to cross a carriageway shall not step onto it without exercising care; they shall use a pedestrian crossing whenever there is one nearby.

(b) In order to cross the carriageway at a pedestrian crossing sign-posted as such or indicated by markings on the carriageway:

(i) If the crossing is equipped with light signals for pedestrians, the latter shall obey the instructions given by such lights;

(ii) If the crossing is not equipped with such lights, but vehicular traffic is regulated by traffic light signals or by an authorized official, pedestrians shall not step into the carriageway while the traffic light signal or the signal given by the authorized official indicates that vehicles may proceed along it;

(iii) At other pedestrian crossings, pedestrians shall not step onto the carriageway without taking the distance and speed of approaching vehicles into account.

(c) In order to cross the carriageway elsewhere than at a pedestrian crossing sign-posted as such or indicated by markings on the carriageway, pedestrians shall not step onto the carriageway without first making sure that they can do so without impeding vehicular traffic.

(d) Once they have started to cross a carriageway, pedestrians shall not take an unnecessarily long route, and shall not linger or stop on the carriageway unnecessarily.

(7) However, Contracting Parties or sub-divisions thereof may impose stricter requirements on pedestrians crossing the carriageway.

Article 21 Behavior of drivers towards pedestrians

1. (b) If vehicular traffic is not regulated at that crossing by traffic light signals or by an authorized official, drivers shall approach the crossing only at a speed low enough not to endanger pedestrians using, or about to use, it; if necessary, they shall stop to allow such pedestrians to cross.

(3) No provision of this Article shall be construed as preventing Contracting Parties or sub-divisions thereof from:

Requiring drivers of vehicles to stop in all cases when pedestrians are using, or about to use, a pedestrian crossing sign posted as such or indicated by markings on the carriageway in the conditions laid down in Article 20 of this Convention, or:

Prohibiting them from preventing or obstructing the passage of pedestrians who are crossing the carriageway at or very near an intersection even if there is at that point no pedestrian crossing sign posted as such or indicated by markings on the carriageway.

Article 23 Standing and parking 3 (a) The standing or parking of a vehicle on the carriageway shall be prohibited:

(i) On pedestrian crossings, on crossings for cyclists, and on level crossings.

Statement On Short-Term Pedestrian Safety Measures

Mrs. V. I. van der Does
Secretary General
International Federation of Pedestrians

May I first of all state in the name of the International Federation of Pedestrians how grateful I am to have been authorized to participate in these most useful activities of the NATO/CCMS project group on Pedestrian Safety. This group, by seeking the worst causes for pedestrian fatality and mutilation and the possible remedies to be envisaged, has had precisely the same purpose as that of the Federation, which tries to "stop the epidemiology at the shortest notice possible."

The approach taken by the project group that in view of the insufficiency of present knowledge concerning pedestrian casualties, one should first make efforts to know more, to understand better, to see more research done, may appear to be rather negative. Quite clearly it is also the view of the Federation that more research must be done, and at the highest scientific level possible; but in 10 or 20 years this will still be the case. But it is my opinion that we should divide our advice into short and long term measures, since pedestrians will continue to be killed tomorrow and during the coming years at an increasing rate. We should also give short term advice.

The sophisticated research done so far by the best town planners of the world — such as Victor Gruen, Prof. Olaf Gunnarson, Prof. Hans Reuhow, Eric Claxton — should not, if possible, be disregarded by the project group, even if one specific method of one specific institute is to be singled out as offering promising returns. In 10 or 20 years' time research will still have to go on, but we must give the tools to stop today's slaughter, as well as provide tools for the coming years.

I wish to take one example, that of traffic segregation such as that now being developed in Delft. This kind of reshaping of some residential

streets only applies to some streets in some towns where speed will be reduced by reshaping a street. However, for the millions of streets where this will not be done, we need simple means, such as thresholds — whether drivers like it or not — to stop death and mutilation in residential areas. This could be compared with typhoid fever and the advice to boil the water before drinking. Now, Mrs. A. will say: "Ah, but Professor X gave me a tablet to put in my glass so I need not first boil the water. That's fine for Mrs. A, and maybe for one thousand Mrs. A's, but the rest of the nations will have to boil their water before drinking in typhoid regions."

Now, as regards the short-term, I wish to propose for the consideration of the group, nine possible tools:

- Segregation (footpaths) of pedestrian traffic from motorized traffic.
- Priority to safe routes to school and playgrounds (footpaths, protected crossings).
- Prohibition of parking at a certain distance before and after pedestrian crossings.
- Prohibition of overtaking in pedestrian crossing zones.
- Prohibition for pedestrians to cross outside pedestrian crossings.
- No "one way traffic" systems in residential areas before the streets have been adapted to pedestrian safety.
- Reduction of traffic speed in residential areas (for example, by reshaping the streets by thresholds, etc.).
- Expanded use of school buses and improved regulations.
- Priority to the improvement of the environment. (Prof. Olaf Gunnarson's Scaft Group Göteborg underlines that "errors are of secondary importance. The environment causes situations where mistakes lead to accidents the environment has to get priority to anything else.")

URBAN PLANNING

Long Term Traffic Planning For The Safety Of The Pedestrian

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Long Term Traffic Planning For The Safety Of The Pedestrian

Ulla Engel
Architect, M.A.A.

INTRODUCTION

Long term traffic planning for the safety of the pedestrians is not an isolated concept and in practice is included in ordinary traffic planning. This planning is necessitated by demands for capacity, access, economy and safety. In this connection Safety planning for the pedestrian constitutes a very small part, and hasn't up until now had any high priority. Decisions on measures for protection of the pedestrian very often take a secondary place in relation to other problems in traffic planning.

Knowledge and experience in traffic safety are concentrated mainly on the car. Research in the field was started with the birth of the car, and has followed it during its growth. The problems concerned with the car and motoring have become the traditional areas of research. A lack of equal knowledge of pedestrian safety often makes planners treat pedestrian traffic as if it were motor traffic. This fundamental lack of knowledge and understanding of the characteristics of the pedestrian and his problems, together with the pedestrian as a dependent part in the ordinary traffic planning, very often leads to absurd solutions. The objective, an increase in the safety for the pedestrian, is often lost.

As an example, take the pedestrian tunnels which are constructed in built-up areas in Denmark. The tunnels are in themselves long and dark. To use them, you have to detour considerably in inconvenient surroundings, compared to the direct way across the street. At the entrance to the tunnels are steps. Thus, "weak" pedestrians, elderly, handicapped people and mothers carrying prams encounter unreasonable difficulty when using this offer of safety.

Few trends can be drawn about long term planning from the rather poor answers to the third chapter of the questionnaire on long term planning circulated by the Pedestrian Safety Working Group.

Therefore, it seems appropriate to support the questionnaire material with results from research conducted by the Swedish planning group

PLANFOR, and with experiences from studies of traffic replanning of existing street-patterns worked out during the past two years in Denmark.

TENDENCIES CONCERNING THE PEDESTRIAN STREET

The pedestrian street has become common in most countries. It has been established not always for the safety of the pedestrian, but very often to encourage shopping. The criteria for these streets are usually based on demands of minimum pedestrian-flows. Very seldom are safety measures established for peak-hour pedestrian flows. On the other hand, safety conditions are improved in these areas normally containing large numbers of pedestrians during daytime hours.

COMMENTS

The pedestrian street, "STRØGET", in Copenhagen, 2 km in length permits traffic of delivery vans between 7 A.M. and 11 A.M. every day. It is crossed by two mixed streets at signalized intersections, and by four mixed one-way streets at unsignalized intersections. No accidents have taken place since the street was closed for vehicular traffic in 1963. It is important here to make it very clear that the safety of these streets is achieved only by closing the street to all ordinary vehicular traffic. This procedure is working without any demands on the pedestrians to behave in ways other than they have been used to.

TENDENCIES CONCERNING NEW TOWNS AND PARTS OF TOWNS

Many new living areas, new parts of towns and entire new towns are built or planned in accordance with the concept of total segregation of traffic. This offers a maximum of safety for the pedestrian, the bicyclists, and the mopedists.

COMMENTS

The safety effect of such a segregated traffic plan is completely dependent on the consistency of other

aspects of the plan. For example, if one succeeded in building a protected pedestrian traffic network, it can be described as functional only if it fulfills the pedestrian demands for convenience and safety, since safety demands are normally given a lower priority than convenience. If the protected pedestrian network is not used 100%, (pedestrians are using shorter and more direct routes along unprotected paths) practical examples indicate that the risk of accidents for pedestrians is the same as the ordinary risk for pedestrians in mixed traffic systems.

It is much easier for the planner to use segregated systems in planning new living areas than for existing areas. He can locate the destinations for the traffic in reasonable proportion to the dwelling units, and can concentrate the destinations and the dwellings. In this way it is simpler and easier to arrange the different traffic systems. Finally he doesn't have to allow for habitual pedestrian behavior, he can dictate the desired habits.

The segregated system now and then imposes completely unreasonable conditions on the users. One example is forcing half of the inhabitants in a new part of a town to walk 400 m. from their flats to parking places and bus stations.

Some examples provide insight into how difficult it is to make a completely segregated system work. In certain cases the smallest link in the system has been made common to the vehicular traffic and the pedestrians. It is very difficult to prevent children from playing on the flagged or asphalted areas and the parking places, where it is possible to roller-skate and to write with chalk, and where the parents spend lots of time working with their cars.

A modification may be necessary for economical reasons and this is not to be disdained. If every single link in the modified system is brought fully and functionally into line, this is preferable to a poorly functioning completely segregated system. Through the development of traffic structures for one of the new polder towns in Holland, among others, one reaches the conclusion that only the car effectively can be kept out of parts of the traffic network, i.e. the pedestrian paths. It is not possible to force the pedestrians to follow only the very limited pedestrian network. Thus, the car alone had to bear the consequences of the stiff, wide-meshed, segregated traffic network by being forced to make detours, while the pedestrians were permitted on every path and street.

TENDENCIES CONCERNING EXISTING TOWNS AND PARTS OF TOWNS

There are few examples of compact radical renewals of traffic systems in existing built-up town areas. The desire to segregate these established traffic structures is however not lacking.

COMMENTS

Physically it is of course possible to twist existing street patterns into horizontal and partly vertical segregated nets for the different groups of road users. To get these users and in particular the pedestrians to follow the net according to its different functions is much more complicated. This has been reflected very clearly in some full scale experiments in Östermalm, Stockholm. Established behavior of the road users is a normal part of established areas. This behavior is partly determined by the destinations for the movements of the road users, and partly by their rational way of choosing their routes. To reach the destinations, routes are chosen based on different criteria. The most frequent of these criteria are the length of the route (the shortest possible), the convenience of the route (few vertical movements as possible), the attractiveness of the route (its content of esthetic values), varied perspectives and clearness in connection with the destinations.

It is particularly difficult to make the pedestrians deviate from these demands for their routes. For economic reasons it is nearly impossible to physically force through any deviation. Forcing the pedestrians to move along longer and more inconvenient routes does not appear reasonable. This is especially true when dealing with the "handicapped" pedestrians, children, and elderly people. Is it therefore possible to build a new segregated street-system, the attractiveness of which exceeds that of the old street system, without moving the destinations of the pedestrians? Both solutions involve considerable financial expenditures. One can therefore pose the question, is it reasonable to have as a target total segregation of an existing street pattern?

REMARKS BY OLOF LOVEMARK

The planner Olof Lovemark (PLANFOR, Center for Traffic and Town Planning Research, Sweden) has in a lecture¹ given examples of the identification of the problems and selection of those it is realistic to

¹ PLANFOR Information Pamphlet No. 27. Pedestrians in Town Centers. PLANFOR, Tornerhjelmiska Huset 252, 20 Helsingborg, Sweden.

work with in planning for the safety of the pedestrians. The examples are project descriptions. One contains the results of extensive behavior studies:

I shall try to inspire a fundamental change in the work of planning by giving a brief description of the aims and the investigation methods of our studies. This discussion will at the same time be an identification of the problems.

In several places in Europe, empirical studies of pedestrian traffic have been carried on during the past ten years. The knowledge in this field is considerable, but has not been made use of efficiently in the planning because of deficiencies in the information system.

The present critical situation regarding the safety, the sanitary situation and the convenience of the pedestrian could probably have been foreseen, if these results had been placed together.

The Distribution Effect

The pedestrian traffic presents a strong distribution of alternative passages, even when there is a clear difference in length of road.

Example - A longer alternative of two passages, that are identical but for the length of road, gets a decrease of use of 10%, only when the distance is 40% longer. An alternative about 20% longer gets a use of 20-30%, when the conditions are the same. (This and following examples are calculations and not exact results of measurements.)

The reason for this extremely important phenomenon is probably partly that people are incapable of judging alternative walking distances even in normal environments and partly that they are disinclined to judge distances rationally.

The consequence of this great distribution on planning will be dealt with later on. The following fundamental conclusion can be made at this stage, however. A general plan for the pedestrian traffic in a town or a group of districts of a town should primarily render an account of:

1. Vehicular traffic routes with traffic places classified according to risks.
2. A localization and a standard of passage points of the pedestrian traffic across these routes and in these traffic places.
3. Measures to conduct the pedestrian traffic to these passage points.

This general plan for the pedestrian traffic forms the strategy for the organization of the pedestrian traffic system and the vehicular traffic system in a

district, and in new planning as well as for traffic regulations.

Up to now, the general planning has only rendered account for pedestrianized streets at the best. The reason for this is probably unrealistic presumptions about the pedestrians' systematic choice of route. (The method is further developed in PLANFOR Information Pamphlet No. 12.)

The Separation Effect

The pedestrian traffic is to a great extent attracted by an increasing degree of separation.

Example - The use of about a 20% longer possible passage in or via the vehicular traffic system, which owing to the distribution effect should have had a use of about 20 - 30% if the grade of separation had been identical, is due to the separation effect reduced to about 10%.

The effect increases with a rising grade of separation, from passage across a four lane route without crossing to a completely separated one. (Vehicular traffic systems without pavements are not efficiently repelling.) The disturbing distribution effect has hereby been compensated to a considerable but by no means sufficient degree.

If, according to what is stated below, the pedestrian traffic system is systematically attracting and the vehicular traffic system is equally repelling with regard to the pedestrians, 100% use of the pedestrian traffic system could be achieved even when the distance of this system is about 10% longer than the alternative via the vehicular traffic system. The relation 10 - 0% is extremely difficult to master. 30 - 20% should be the norm.

Another fundamental principle has hereby been identified. When organizing a district in a town the aspects of the pedestrian traffic must be primary and the easy and fast passage of the vehicular traffic must on this level be completely secondary. The development of planning has only taken slow steps towards this principle so far.

Other Environmental Characteristics

Visual Clearness - If the pedestrian from the point where he is choosing his direction or immediately before that point can see his goal or something associated with it in the direction of one alternative, this alternative is attracting.

This great importance of visual clearness in the separated system evidently makes it possible to adjust the effect of unsatisfactory distance relationships.

Inversely the effect can be disastrous for the use, e.g., when houses are built with staircase wells with entrances on both sides of the house.

Example — If one of two alternatives is about 30% longer, the use decreases from about 20% to about 10%, when the destination point of the shorter alternative is visible from the choosing point. The use of the longer alternative increases inversely to about 30%, if the visual clearness refers to this alternative.

Varied Perspectives — A comparatively great attracting effect is received by a certain complexity, defined as more than two variations in the direction of movement of 90 degrees. This can be explained by the fact that a road with short varied perspectives is regarded as shorter and more interesting.

Example — The total effect of visual clearness and varied perspectives, (these qualities are by no means impossible to combine) will increase the use about 50%, if the distance and the other environmental qualities are equivalent. This means that use of a 20% longer alternative increases from about 25% to about 50% if visual clearness and varied perspectives are part of this alternative.

Deviation from the Destination Point — Pedestrians tend to a rather considerable extent to minimize the deviation from the approximate direction towards the destination point instead of minimizing the number of changes of direction. In this case the alternative with few changes of direction does not stand for a lack of varied perspectives.

The effect will be that different alternatives may be chosen for every direction. This effect is in certain planning cases extremely important for the choice of the separated pedestrian system. Deviation of 150 degrees especially at the start of a walk should systematically be avoided for routes intended to be chosen and be aimed at those intended not to be chosen.

Partial Round About Way — For instance in a vertical separation, a side movement to a bridge or tunnel is often implied and thereafter another side movement. When it is physically possible to pass straight on a partial round about way, it is disastrous to the use of the separation. Repelling measures that have failed to appear could put considerable parts of the pedestrian traffic system out of function, sometimes with extremely severe conflicts. As a consequence post insight as to the pedestrian risks is available.

This effect limits the localization of stepping places in vehicular traffic systems which need vertical separation to protect the pedestrians.

The effect also limits the localization of shopping centers within comfortable reach of cars.

Differences of Level — Differences of level in the shape of ramps, sloping less than 1:10 are considerably less repelling than stairs. Downhill ramps are attracting. The repelling effect of stairs increases faster than the number of steps. Stairs should consequently be avoided where ramps are possible.

Inevitable stairs with more than 10 steps should be divided in sections and out of consideration for prams and handicapped people be combined with ramps in another position.

The hypothetic relation figure 1:10 between horizontal surface and difference of level is completely misleading.

Lighting, Shelter Against Rain and Wind, the State of the Roads. **Example** — About 20% stated in an interview study that darkness and a bad state of the roads altered their choice of route. About 10% gave hard wind and rain as their reason.

Conclusion

Rational analyses of the use of sketched pedestrian traffic systems have formerly hardly been possible on the level of detail planning or in general planning. The results rendered in the above account make analyses of this kind possible.

The use will to a great extent be the determining factor in the organization of pedestrian traffic systems as well as for buildings, vehicular traffic systems and parking.

In the present stage 2 of this theme, study methods are being developed to achieve optimal convenience for the pedestrian traffic system by conscious localization of primary visiting points. This premises, in any case on the development level, prognostications of probable pedestrian traffic quantities.

METHOD FOR THE PLANNING OF PEDESTRIAN TRAFFIC SYSTEMS IN MIXED STREETS (PLANFOR Information Pamphlet No. 16.)

The Use of Crossings Without Light Control in 4-laned Streets

Example — A round about way of 10 meters reduces the use of this kind of crossing to 90%. A round about way of 30 meters gets a use of 50 - 70%. The use seems to be comparatively uninfluenced by the extent of the vehicular traffic when the 24-hour traffic approaches 10,000 vehicles.

This planning case implies very careful analyses of the localization of entrances and stopping places in relation to the localization of crossings. Systematically located railings and other repelling measures are also necessary. (Regarding a vehicular traffic intensity where light control is necessary, see the following section in this article.)

The Use of Crossings without Light Control in 2-lane Streets

Example – A round about way of 10 meters already reduces the use by up to 50% of the pedestrian traffic. Even when there is no round about way there is a reduction of the use of 50%, i.e., people are slanting the street before a crossing without gaining length of way.

The shaping of narrow mixed streets can consequently not be based upon crossings. A development effort to find more realistic forms is necessary e.g., driving over curb stones, much reduced maximum speeds wide crossing spaces or special-marked driving areas.

The Use of Light Controlled Crossings

Example 1 – A maximum waiting time of 65 seconds reduces use 10 and 25% in streets with 3 and 2 driving lanes respectively. The traffic intensity was about 10,000 vehicles per 24 hours. In neither case was there a round about way. A crossing is an integrated part of the pedestrian traffic system. The standard of crossings can not depend on desire for capacity and fast passage for the vehicular traffic as these crossings then will cease to function. Thus all pedestrian traffic flows must systematically be marked, be provided for or be directed by repelling measures.

Example 2 – If an extension of the length of road of about 50 meters is added to the above mentioned example the use decreases to practically zero.

If localization as well as time delay cannot be adapted to every important pedestrian traffic flow and if repelling measures cannot be taken, the prospects of use are remote.

Example 3 – A maximum waiting time of 35 seconds in a 2-laned street with about 3,000 vehicles per 24 hours reduced the use about 30%, in spite of the fact that there was no round about way.

Narrow mixed streets consequently don't function with light controlled crossings either, in spite of short waiting times.

The Readiness and Ability of Drivers to Give Free Way at Crossings

At two closely located crossings without light control, 25 meters apart, no observation of a lower regard for the pedestrians was made at the second crossing compared with the first one.

The custom of locating crossings with regard to drivers' ability to observe probably means unrealistic long distances between the crossings. Other results of measuring indicate that the demands for visual clearness at crossings due to curbstone parking, have been much underestimated.

Example 2 – When the capacity of a traffic place gets strained, the incorrect behavior of the car driver rises dramatically as he operates during a pedestrian phase. The standard light controlled crossings are consequently completely unrealistic when a separate phase for pedestrians is "the most difficult" to provide for.

Conclusion

The planning of pedestrian traffic systems in mixed streets, the kind of street that will have about half the pedestrian traffic in future central parts of a town, has really been based upon false, ideal pictures of the reasonable behavior of pedestrians and drivers.

An extensive revision of plans for central business districts and for other central parts as well will be inevitable in the seventies, with a heavily reduced capacity for the vehicular traffic and for parking as a consequence.

As mixed traffic systems cannot be perfect regarding the safety of pedestrians, a method to achieve the optimal safety with the aid of risk figures will be developed in stage 2 of this theme of the study.

METHOD FOR THE PLANNING OF OPTIMAL MEASURES FOR TRAFFIC RENEWAL IN THE PRESENT MIXED STREETS CONCERNING THE SAFETY OF PEDESTRIANS AND CYCLISTS AND COSTS. (From PLANFOR Information Pamphlet No. 17.)

From a financial point of view there is an extremely great demand for urgent measures for traffic renewal. A method is necessary, which can select the optimal measures in a town at any time.

The method should also precisely define necessary optimal measures to maintain the existing safety in a mixed traffic system. With a new pedestrian traffic system or a new parking system there is the

possibility of increased risk quantities for pedestrians and cyclists.

The method should also estimate the speed of the renewal in a town to enable that this speed is objectively adapted to the demands for standards in new planning.

Method

- Measuring in stages of pedestrian traffic flows, bicycle traffic flows and vehicular traffic flows.
- Estimation of risk quantities.
- Alternative regulations are studied for the largest risk quantities.
- Classification of the regulations according to the priority figure: risk quantity reduction/regulation cost.

Theory

$$RM_i = G_i \times R_g \times R_t \times R_b \times R_l$$

where

RM_i = total risk quantity for pedestrians in the passage line i.

G_i = number of pedestrians/time unit in the passage line i.

R_g = risk figure due to type of passage or of position of passage line in relation to crossing and traffic place.

R_t = risk figure due to number of driving lanes.

R_b = risk figure due to number of car trips/time unit.

R_l = risk figure due to lighting conditions.

Example of Risk Figure, R_g

(Some information is available about the other risk figures in PLANFOR Information Pamphlet No. 17.)

On zebra crossing in junction.	Risk figure 0.7
More than 50 meters from a zebra crossing between junctions.	Risk figure 1.0
Within 20 meters from a junction without crossings of any kind.	Risk figure 1.3
Within 50 meters from a junction with zebra crossings.	Risk figure 2.5

On light controlled crossings.	Risk figure 0.2
On a zebra crossing between junctions.	Risk figure 0.2
Within 50 meters from a zebra crossing between junctions.	Risk figure 1.2
Within 50 meters from a light controlled crossing in junctions.	Risk figure 6.6
Within 50 meters from a light controlled crossing between junctions.	Risk figure 1.2

Further Development of the Method

In order to give a concrete picture of method and theory an account of the outlines of studies of the central parts of a medium sized town is below.

- Measuring of all pedestrian traffic flows across 4-laned streets with more than about 8,000 per mean 24 hours a year.
- Measuring of bicycle flows in traffic places without light control with 4-laned street with more than 10,000 vehicles per mean 24 hours a year.
- Classification of the risk quantities of the pedestrian traffic. Ranking of bicycle flows in previously measured traffic situations according to size in different classes of vehicular quantities.
- Distinguishing of optimal regulations, details or complexes according to the principles mentioned above.
- Comparisons with local statistics of accidents.
- Realization in stages and control of the results.

In a new report² Lövmärk presents the results of a practical implementation of the theories from PLANFOR Information Pamphlet No. 17.

The report renders an account of a practical application of the method, developed by the PLANFOR Group, of determining travellers' risk of personal injury by the recording of behavior.

Previously, in order to determine the risk of travellers it was necessary to resort to analyzing the traffic accidents that had occurred.

The greatest advantage of the method of recording behavior is that it gives an immediate and precise description of the risk of travellers which is of great importance, for example by assessing the safety effects of a traffic regulation. For a comparable

²PLANFOR Information Pamphlet No. 57. TRAFFIC SAFETY IN UPPSALA TOWN CENTER. PLANFOR, Tornesholmaka Huset 252, 20 Helsingborg, Sweden.

evaluation by means of accident data at least two years' accident material is required.

The principle of the method is that the risk of personal injury, to which travellers are exposed, is in direct proportion to the number of serious conflict situations, in which travellers in a flow are involved.

Serious conflict situations arise as a consequence of either an uncontrolled conflict-averting behavior or a dangerous traffic behavior which produces an uncontrollable situation. In both cases the travellers involved must pass one another at a distance of less than about 1 m, partly due to the means of conveyance and the type of traffic environment. The risk of personal injury varies according to the type of traffic environment — traffic situation — means of conveyance (conflict class) and the volume of the vehicle flow creating the conflict.

The amount of risk, which is a measure of the probability of an accident causing personal injury occurring, can be estimated only on the knowledge of the volume of the flow of travellers and the risk of personal injury in the existing classes of conflict.

The recording of the travellers' behavior and serious conflict situations is made by direct observation. To achieve a uniform interpretation of the chosen definitions a preceding training period is required for the observers and also that control studies are carried out both before and during the recording. The recording of the travellers' behavior is made by an electronic measuring device. The evaluation is based on computer data.

In the report an account is rendered of an application of the method, partly in order to assess the safety effects of the traffic regulation introduced in the center of Uppsala on October 1, 1972, and partly to produce the first stage in the building of a general behavior data bank which is to be the basis of the development of a municipal program of measures against traffic accidents.

By means of this method the planning can be based on a precise description of the present risk and amount of risk, probable alteration of these and drawing up of a precisely defined aim in respect of traffic safety.

The evaluation of the effect of the Uppsala Regulation showed that the traffic safety improved somewhat in respect of all means of conveyance which primarily is due to the measures that were taken in those routes where the traffic was increased owing to the regulation.

The total reduction in risk of the Uppsala Regulation was:

Pedestrian traffic	5%
Cycle traffic	2%
Car traffic	11%
Total means of conveyance	5%

CONCLUSIONS

The pedestrians represent a problem in traffic. There is a number of recommendations to solve this problem. The most popular of these seems to be to separate the different groups of road users horizontally and, if possible, vertically.

It could look like a cure-all has been found for pedestrian accidents. For the planner the system is clear and easy to work with. The theory is simple and understandable.

Why then is segregating every street pattern not recommended? Why hasn't more been accomplished in a field where everyone seems to know the correct answers?

To segregate when building new towns or parts of towns doesn't have to mean any insurmountable financial loading. To segregate effectively, so that the expected safety is obtained through acceptance by the pedestrians, is difficult. In England, there are examples of new towns, in which the traffic systems have not been accepted and are not used in the planned way. There are also examples of the opposite.

Why the difference in the use of the systems? In certain cases planners have, more or less at random, succeeded in devising a system which the pedestrians will accept and use.

To segregate traffic in existing areas is very expensive, particularly if vertical separation is used. If you cannot afford to force through a safe behavior in this way, the functional success of the system is completely dependant on how seriously you treat the rules for the behavior of the pedestrian. These rules have been described by Lövmärk. Another possibility is, as already mentioned, to move the destinations of the pedestrians to centralized shops, and institutions, and living areas, etc. This offers an opportunity to simplify segregation of the traffic system.

This means however, that you have to rebuild the existing town or part of town at considerable expense which is not completely acceptable.

What in general seems to constitute the most serious problem in the planning of new traffic systems or in the replanning of existing traffic systems for the safety of the pedestrian is to know

the advantages and the limits of the segregated and of the mixed traffic systems. Furthermore, it is important to know how to use these systems, totally or modified, according to the conditions, i.e., the structure and the economy for new areas. For existing built-up areas, the existing town-structure, centralized or decentralized, the reasonableness (esthetics or historical) in changing this structure, and the economy are equally important. It requires a deep understanding of the problems to be able to administrate the system according to the criteria already mentioned. First of all one has to be able to identify the problems in each case of planning and to realize that standard solutions do not exist.

RECOMMENDATIONS

Standard solutions for planning are not practical. As a conclusion of this paper it seems obvious that pedestrian safety planning must be based partly on the physical data according to the location and partly on a realistic estimation of the ability and the willingness of the pedestrian to use the safety measure. The key words must therefore be *behavior*

studies and analyses of the environment. The following are necessary:

- Centrally organized records of the frequency of safe, dangerous and accident producing behaviors in combinations of traffic/environmental situations with accident rates.
- Centrally organized records of traffic environments with high accident rates, analyses of the environment, i.e., location of possible immediate destinations of the pedestrian traffic, location of alternative routes and examination of their contents according to the demands (short, comfortable, attractive and safe), and the present behavior of the pedestrians.
- Statistical records of the immediate destinations of the movements of pedestrians involved in traffic accidents.
- Central evaluation of above three items.
- Local planning according to risk, recommended principles and analysis of data from the central organization. The risk is derived from local registration of number of travellers multiplied by frequency.
- International exchange of data.

Pedestrians In Town Centers — A Summary Of Some Research Projects

Olof Löfmark
Director, PLANFOR

THE PRESENT SITUATION IN OUR TOWN TOWN CENTERS FROM A SAFETY POINT OF VIEW

The pedestrians meet with about 40-50% of the total number of injuries in road accidents, the bicycles and the mopeds with 20-30%. These categories consequently represent $\frac{1}{2}$ of the injuries, besides that they are on the average more serious than the remaining $\frac{1}{2}$ concerning the drivers and the passengers of cars.

The risks for the pedestrians and the cyclists increase several times faster than the increase of the vehicular traffic volumes. An increase of up to 50%, for example, of a vehicular traffic flow means an increase of roughly 200% of the risks for the pedestrians. This trend of development due to car intensity and urbanization should be considered in the light of the fact that people in general get an ever increasing knowledge of the real significance of injuries in road accidents. Sharpened crises of confidence can be expected in the near future.

The total demand for urgent measures in the town centers of today concerning the safety of pedestrians and cyclists is extremely extensive from a financial point of view.

REGARDING THE SITUATION OF PLANNING THE FOLLOWING CAN BE ADDED

The long-time planning has during the sixties been characterized by a great inability or irresolution to abandon former philosophies about planning for so-called unmuffled vehicular traffic, or for the big cities, to maintain approximately the existing capacity of the vehicular traffic, expressed in offers of parking as well as of trips.

The short-time planning of measures for pedestrian and bicycle traffic has to a great extent failed to appear, primarily owing to the fact that these aspects were completely subordinated to the ambitions of capacity, when the change to right-hand traffic took place.

Regarding the plans of central business districts of recent years, it may be added, that they have been called convenient for pedestrians only because of a few pedestrian shopping streets. I hope to be able to prove that this criterion is insufficient.

THE MOST IMPORTANT REASONS FOR THE THREATENING PICTURE OF THE FUTURE AND FOR THE PRESENT SERIOUS SITUATION

The planning has to a great extent had to be based upon unfounded assumptions about the behavior and estimations of the pedestrians and the drivers as well as upon incomplete methods of planning.

The planners have to a great extent regarded development and empiric work as the concerns of the public authorities and the universities.

With reference to what has taken place during the sixties, I would like to describe this view on research and development as out of touch with reality. It is only in close connection with practical planning that the researchers may be able to identify the important problems, i.e., the municipal administration should to a much higher degree than hitherto take an active part in development work.

IDENTIFICATION OF PROBLEMS

I shall try to be an inspirer of a fundamental change in the work of planning by giving a brief description of the aims and the investigation methods of our studies. This expose will at the same time be an identification of the problems.

In several places in Europe empirical studies of pedestrian traffic have been carried on during the past ten years. The knowledge in this field is considerable, but has not efficiently been made use of in the planning because of lacks in the information system.

The present critical situation regarding the safety, the sanitary conditions and the convenience of the pedestrians could probably have been foreseen, if these results had been placed together.

Themes Of Study — (Figure within parenthesis refers to the list of published reports in this article. P = present.)

METHOD FOR THE PLANNING OF SEPARATED PEDESTRIAN SYSTEMS AND OF THE LOCALIZATION OF VISITING POINTS

- Background:** 100% use, when an alternative passage means "not acceptable conflict."
A minimizing of the total pedestrian traffic work by a conscious localization of visiting points.
- Method:** Studies of choices of road.
Generity - and attractivity figures.
- Stage 1:** Method of prognostication regarding use.
- Stage 2:** General lines of direction. (15)
Method for obtaining optimal convenience. (P)

METHOD FOR THE PLANNING OF PEDESTRIAN SYSTEMS IN MIXED STREETS

- Background:** About 50% of the pedestrian traffic in future mixed streets.
- Method:** Use of crossings, behavior at crossings.
- Stage 1:** Method of prognostication regarding use. (16)
- Stage 2:** Method for obtaining optimal safety. (P)

METHOD FOR THE PLANNING OF BICYCLE SYSTEMS IN MIXED STREETS

- Background:** About 50% of the bicycle traffic in future mixed streets.
Coordination of pedestrian - and bicycle traffic, 50%.
- Method:** The behavior of cyclists and car drivers in traffic environments and traffic situations with high risk figures.
- Stage 1:** Preparatory study of the purposes and the dependence on climate of the bicycle traffic. Preliminary studies of behavior. (13)
- Stage 2:** Method of prognostication about how cyclists will use planned traffic routes and about the risks that they will be running. (P)

METHOD FOR THE PLANNING OF OPTIMAL MEASURES FOR THE RENEWAL OF TRAFFIC SYSTEMS IN THE PRESENT MIXED STREETS

REGARDING THE SAFETY OF PEDESTRIANS AND CYCLISTS AND REGULATION COSTS

- Background:** Optimal measures must continually be taken.
- Method:** A combination and development of a series of risk figures.
- Stage 1:** Outline of a method regarding pedestrian traffic. (17)
- Stage 2:** Further development by theoretical application. (Not yet started.)

METHOD FOR THE WEIGHING OF DIFFERENT FACTORS OF CONVENIENCE IN A PUBLIC TRANSPORTATION SYSTEM

- Background:** The organization can be given alternative shapes on every cost level owing to how the factors are reciprocally preferential.
- Method:** Alternative and contrary proposals of improvements to selected groups with specific travel conditions. Two cost levels.
- Stage 1:** Preparatory study, test of method.
Walking distance, access to seats, bus frequency, total travel time. (19)
- Stage 2:** Malmö: walking distances, weather shelter, on footpath and at stopping place, bus frequency, conditions when changing buses, total travel time.
Comparative studies in three towns of different size regarding the total travel time. (P)

THE STRUCTURE OF PARKING IN CENTRAL BUSINESS DISTRICTS BASED UPON DEMANDS FOR SAFETY FOR PEDESTRIANS AND CYCLISTS AND ACCEPTED WALKING DISTANCES

- Background:** Defined demands for safety for pedestrians and cyclists based upon studies of behavior will be determining for a possible localization of parking. The convenience of the pedestrian system will be determining for the influence and efficiency of the parking.
- Method:** A combination of the results from the other studies:
Accepted walking distance (4)

Weather influence (2)
The mixed system (16, 13, 17)
(P)

NOTE: Below follows an account of the results from the themes of study. The readers who want more complete information are referred to the report in question.

METHOD FOR THE PLANNING OF SEPARATED PEDESTRIAN SYSTEMS. (From Report No. 15.)

The Distribution Effect

The pedestrian traffic presents a strong distribution of alternative passages, even when there is a clear difference in length of road.

Example – A longer alternative of two passages, that are identical but for the length of road, gets a decrease of use of 10%, only when the distance is 40% longer. An alternative about 20% longer gets a use of 20-30%, when the conditions are the same. (This and following examples are calculations and no exact results of measurements.)

The reason for this extremely important phenomenon is probably partly that people are incapable to judge alternative walking distances even in normal environments and partly that they are disinclined to judge distances rationally.

The consequence of this great distribution for the planning will be dealt with later on. The following fundamental conclusion can be made at this stage, however. A general plan for the pedestrian traffic in a town or a group of districts of a town should primarily render an account of:

- Vehicular traffic routes respectively traffic places classified according to risks.
- A localization and a standard of passage points of the pedestrian traffic across these routes and in these traffic places.
- Repelling measures to conduct the pedestrian traffic to these passage points.

This general plan for the pedestrian traffic forms the strategy for the organization of the pedestrian traffic system and the vehicular traffic system in a district in new planning as well as at traffic regulations.

Up to now the general planning has only rendered account for pedestrianized streets at the best. The reason for this is probably unrealistic presumptions about the pedestrians' systematic choice of route. (The methodics are further developed in report No. 12.)

The Separation Effect

The pedestrian traffic is to a great extent attracted by an increasing degree of separation.

Example – The use of about 20% longer possible passage in or via the vehicular traffic system, which owing to the distribution effect should have had a use of about 20-30% if the grade of separation had been identical, is due to the separation effect reduced to about 10%.

The effect increases with a rising grade of separation, from passage across a four lane route without crossing to a completely separated one. (Vehicular traffic systems without pavements are not efficiently repelling.) The disturbing distribution effect has hereby been compensated to a considerable but by no means sufficient degree.

If, according to what is stated below, the pedestrian traffic system is systematically formed attracting and the vehicular traffic system is formed equally repelling with regard to the pedestrians, a use of the pedestrian traffic system of 100% could be achieved even when the distance of this system is about 10% longer than the alternative via the vehicular traffic system. The relation 10 - 0% is extremely difficult to master. 30 - 20% should be normating.

Another fundamental principle has hereby been identified. When organizing a district in a town the aspects of the pedestrian traffic must be primary and the easy and fast passage of the vehicular traffic must on this level be completely secondary. The development of planning has only taken slow steps toward this principle so far.

Other Environmental Characteristics

Visual Clearness – If the pedestrian from the point where he is choosing his direction or immediately before that point can see his aim or something associated with it in the direction of one alternative, this alternative is attracting.

This great importance of visual clearness in the separated system makes it evidently possible to adjust the effect of unsatisfactory distance relation. The effect can inversely be disastrous for the use, when e.g. houses are built with staircase-wells with entrances on both sides of the house.

Example – If one of two alternatives is about 30% longer, the use decreases from about 20% to about 10%, when the destination point of the shorter alternative is visible from the choosing point. The use of the longer alternative increases inversely to about 30%, if the visual clearness refers to this alternative.

Varied Perspectives — A comparatively great attracting effect is received by a certain complexity, defined as more than two variations in the direction of movement of 90 degrees. This can be explained by the fact that a road with short varied perspectives is regarded as shorter and more interesting.

Example — The total effect of visual clearness and varied perspectives, and these qualities are by no means impossible to combine, will be an increase of the use of about 50%, if the distance and the other environmental qualities are equivalent. This means that use of a 20% longer alternative increases from about 25% to about 50% if visual clearness and varied perspectives are referred to this alternative.

Deviation from the Destination Point — Pedestrians tend to a rather considerable extent to minimize the deviation from the approximative direction towards the destination point instead of minimizing the number of changes of direction. In this case the alternative with few changes of direction does not stand for a lack of varied perspectives.

The effect will be that different alternatives may be chosen for every direction. This effect is, in certain planning cases, extremely important for the choice of the separated pedestrian system. Deviations of 180 degrees especially at the start of a walk should systematically be avoided for routes intended to be chosen and be aimed at for those intended not to be chosen.

Partial Round About Way — For instance with a vertical separation at a bridge or tunnel, a side movement is often required and thereafter another side movement. When it is physically possible to go straight on, people will do so rather than use a partial round about way of this kind. In general people have a poor insight to the risks involved. Consequently in a situation of this kind they will tend not to use facilities built for their safety.

This effect limits the localization of stopping places in vehicular traffic systems which need vertical separation to protect the pedestrians.

The effect also limits the localization of shopping centers within comfortable reach for cars.

Differences Of Level — Differences of level in the shape of ramps, sloping less than 1:10 are considerably less repelling than stairs. Downhill ramps are attracting. The repelling effect of stairs increases faster than the number of steps. Stairs should consequently be avoided where ramps are possible.

Inevitable stairs with more than 10 steps should be divided in sections and out of consideration for prams

and handicapped people be combined with ramps in another position.

The hypothetic relation figure 1:10 between horizontal surface and difference of level is completely misleading.

Lighting, Shelter Against Rain and Wind, the State of the Roads. **Example** — About 20% stated in an study that darkness and a bad state of the roads altered the choice of route. About 10% stated hard wind and rain as the reason.

CONCLUSION

Rational analyses of the use of sketched pedestrian traffic systems have formerly hardly been possible either on the level of detail planning or in general planning. The results rendered account for above make analyses of this kind possible.

The aspect of the use will to a great extent be determining for the organization of pedestrian traffic systems as well as for buildings, vehicular traffic systems and parking.

In the present stage 2 of this theme of study, methods are being developed to achieve optimal convenience for the pedestrian traffic system by conscious localization of primary visiting points. This is based on knowledge of the source and amounts of the pedestrian traffic.

METHOD FOR THE PLANNING OF PEDESTRIAN TRAFFIC SYSTEMS IN MIXED STREETS. (From Report No. 16.)

The Use of Crossings Without Light Control in 4-lane Streets. **Example** — A round about way of 10 meters reduces the use of this kind of crossing to 90%. A round about way of 30 meters gets a use of 50 - 70%. The use seems to be comparatively uninfluenced by the extent of the vehicular traffic when the 24-hour traffic approaches 10,000 vehicles.

This planning case implies very careful analyses of the localization of entrances and stopping places in relation to the localization of crossings. Systematically located railings and other repelling measures are also necessary. (Regarding a vehicular traffic intensity where light control is necessary, see the following section on traffic renewal from report number 17.)

The Use of Crossings Without Light Control in 2-lane Streets. **Example** — A round about way of 10 meters already reduces the use with up to 50% of the pedestrian traffic. Even when there is no round about

way there is a reduction of the use of 50%, i.e., people are slanting the street before a crossing without gaining length of way.

The shaping of narrow mixed streets can consequently not be based upon crossings. A development work to find more realistic forms is here necessary, e.g., driving over curbstone, much reduced maximum speed, wide crossing spaces or special-marked driving areas.

The Use Of Light Controlled Crossings

Example 1 - A maximum waiting time of 65 seconds reduces the use with 10-25% in streets with 3 or 2 driving lanes respectively. The traffic intensity was about 10,000 vehicles per 24 hours. In neither case was there a round about way. A crossing is an integrated part of the pedestrian traffic system. The standard of crossings can not depend on wishes for capacity and fast passage for the vehicular traffic as these crossings then will cease to function. Thus all pedestrian traffic flows must systematically be distinguished, be provided for or be directed by repelling measures.

Example 2 - If an extension of the length of road of about 50 meters is added to the above-mentioned example the use decreases to practically none.

If localization as well as time delay cannot be adapted to every important pedestrian traffic flow and if repelling measures cannot be taken, the prospects are absurd.

Example 3 - A maximum waiting time of 35 seconds in a 2-laned street with about 3,000 vehicles per 24 hours reduced the use with about 30%, in spite of the fact that there was no round about way.

Narrow mixed streets consequently don't function with light controlled crossings either, in spite of short waiting times.

The Readiness And Ability Of Car Drivers To Give Free Way At Crossings

Example 1 - At two closely located crossings without light control, 25 meters apart, no observation of a lower regard for the pedestrian was made at the second crossing compared with the first one.

The custom of locating crossings primarily with regard to car drivers often results in unrealistic long distances between the crossings. Other observational results indicate that the requirements for visual clearness at crossings because of curbstone parking, have been significantly underestimated.

Example 2 - When the capacity of a traffic place gets strained, incorrect behavior of the car driver rises dramatically as he turns through a pedestrian phase of the traffic light. The current standards for light controlled crossings are consequently completely unrealistic when the separate phase for pedestrians is the most difficult to provide for and control.

CONCLUSION

The planning of pedestrian traffic systems in mixed streets, the kind of street that will have about half the pedestrian traffic in future central parts of a town, has really been based upon false, ideal pictures of the reasonable behavior of pedestrians and drivers.

An extensive revising of plans for central business districts and for other central parts as well will be inevitable in the seventies, with a heavily reduced capacity for the vehicular traffic and for the parking as a consequence.

As mixed traffic systems cannot be perfect regarding the safety of pedestrians a method to achieve the optimal safety with the aid of risk figures will be developed in stage 2 of this theme of study.

METHOD FOR THE PLANNING OF A BICYCLE TRAFFIC SYSTEM IN MIXED STREETS. (From Report No. 13.)

Future Purposes Of The Traffic

The probable purposes of the bicycle traffic in future central parts of towns can be illustrated in the following way.

In an interview study in Malmö residents who had a convenient distance of walking to a bus route with a high frequency were selected. This study indicated that the bicycle traffic had as great a part as the bus traffic, about 25% each. The bicycle traffic is twice as attractive when the bus trip involved a change of buses.

At the time interval 15-25 minutes of a bicycle trip the bicycle traffic answered for about 40% of the total number of trips. The study was made in May and concerned resident work trips. In the winter the part of the cyclists was reduced to half the size and in Stockholm to 1/4. As the part of car trips to the central parts of towns in spite of planned parking is getting smaller in big towns as well as in towns of average size, the importance of the bicycle will increase considerably. That means that the decreasing trend since 1945 will be broken, provided that the bicycle traffic is not further assaulted.

The bicycle traffic system should systematically be planned into the central parts of towns not only for ethics, that is safety reasons, but also because the bicycle is an important way of travelling.

Strategy Of Planning

The pedestrian traffic system, spatially separated from the vehicular traffic in a town's central parts, cannot for technical-financial reasons be more extensive than that required to serve half the bicycle traffic. This assumes that the system has no inconvenient differences of level. If it does the fraction of the bicycle traffic that can be provided for in this system is still smaller.

Thus a system with quantitatively small purposes for cars should systematically be adapted to the needs of the pedestrian traffic. In this system the bicycle traffic could be taken charge of in a realistic way.

Studies Of Behavior

Through preliminary analyses of risk figures the following types of traffic environments and traffic situations can be mentioned as strategic for the safety in the mixed traffic system and particularly in its crossings with 4-laned streets.

- Lane driving and turning left in crossings without light control.
- Passage across 4-laned street in crossings without light control.

According to preliminary results from studies of dangerous behavior in traffic of cyclists and car drivers in selected situations and environments 10,000 vehicles may be mentioned as a critical quantity per 24 hours in a 4-laned street. By this intensity 1/3 - 1/2 of the bicycle trips can be classified as dangerous in the rush hour either due to the behavior of the cyclists or the car drivers.

Summary Of Methods Of Planning

- Streets that cannot be adapted to the bicycle traffic are selected according to criteria for the lowest safety acceptable.
- The passage points of the bicycle traffic across these streets are precise concerning position and standard.
- Repelling measures are precise e.g. prohibitions, railings.
- The other parts of the street net, the mixed traffic system and the separated pedestrian system, are adapted to streets and bicycle passage points.

A rational planning implies risk figures to make the existing risk quantities clear and data concerning

use for the estimation of the probable use of precise passage points and possible courses.

The work of stage 2 will especially aim at these purposes.

METHOD FOR THE PLANNING OF OPTIMAL MEASURES FOR TRAFFIC RENEWAL IN THE PRESENT MIXED STREETS CONCERNING THE SAFETY OF PEDESTRIANS AND CYCLISTS AND COSTS (From Report No. 17.)

Due to financial considerations there is an extremely great demand for urgent measures for traffic renewal. A method is necessary that will permit selection of the optimal measures in a town at any time.

The method should allow optimal measures of existing safety in a mixed traffic system to be maintained, otherwise a new pedestrian traffic system or a new parking system could result in increased risk quantities for pedestrians and cyclists.

The method should also estimate the speed of renewal in a town to enable proper phasing of standards in new planning.

Method

1. Measuring in stages of pedestrian traffic flows, bicycle traffic flows and vehicular traffic flows.
2. Estimation of risk quantities.
3. Alternative regulations are studied for the largest risk quantities.
4. Classification of the regulations according to the priority figure: risk quantity reduction/regulation cost.

Theory:

$$RM_i = G_i \times R_g \times R_t \times R_b \times R_l$$

where

RM_i = total risk quantity for pedestrians in the passage line i.

G_i = number of pedestrians/time unit in the passage line i.

R_g = risk figure owing to type of passage or of position of passage line in relation to crossing and traffic place.

R_t = risk figure owing to number of driving lanes.

R_0 = risk figure owing to number of car trips/time unit.

R_1 = risk figure owing to lighting conditions.

Example Of Risk Figure, R_0

(Some information is available about the other risk figures in report No. 17.)

On zebra crossing in junction.	Risk figure 0.7
More than 50 meters from a zebra crossing between junctions.	Risk figure 1.0
Within 20 meters from a junction without crossings of any kind.	Risk figure 1.3
Within 50 meters from a junction with zebra crossings.	Risk figure 2.5
On light controlled crossings.	Risk figure 0.2
On a zebra crossing between junctions.	Risk figure 0.2
Within 50 meters from a zebra crossing between junctions.	Risk figure 1.2
Within 50 meters from a light controlled crossing in junctions.	Risk figure 6.6
Within 50 meters from a light controlled crossing between junctions.	Risk figure 1.2

Further Development Of The Method

In order to give a concrete picture of the method and theory covered below, an outline of the studies of the central parts of a medium sized town is given.

- Measuring of all pedestrian traffic flows across 4-laned streets with more than about 8,000 vehicles per mean 24 hours a year.
- Measuring of bicycle flows in traffic places without light control with 4-laned street with more than 10,000 vehicles per mean 24 hours a year.
- Classification of the risk quantities of the pedestrian traffic. Ranking of bicycle flows in formerly precise traffic situations according to size in different classes of vehicular quantities.
- Distinguishing of optimal regulations, details or complexes according to the principles mentioned above.
- Comparisons with local statistics of accidents.
- Realization in stages and control of the results.

METHOD FOR THE WEIGHING BETWEEN DIFFERENT FACTORS OF CONVENIENCE IN A MASS TRANSIT SYSTEM. (From Report No. 19.)

Principle

The factors of convenience that together constitute the convenience of a trip by a public transportation system will be weighed in proportion to the values of passengers on every cost level.

It is e.g. not correct to make strict demands for short walking distances and not at the same time mention the aim considering e.g. the total time of travelling and the bus frequency.

The Total Time Of Traveling

A most strategic line to work upon for the organizing of the mass transit system of towns and thus also for the structure of towns is to give priority to the total time of travel from door to door.

In a preliminary study in Malmö, the following preliminary results were achieved. A trip of more than 40 minutes causes an increase to nearly 100% of the number of passengers who give priority to a reduction in the total time of travelling. The two walking distances at each end and the time of waiting amounted to up to 20 minutes.

This would mean that somewhat more than 20 minutes are at disposal for the organization of the bus trip component including the changing-of-bus component.

Walking Distance

When the walking distance was about 300 m the share that gave priority to a reduction of the walking distance formed a small minority. When the distance was about 500 m the share was three times as big. This may be compared with former results, report No. 4, indicating that the share of pedestrians along a public transportation system of high standard falls steeply from about 400 m to about 1,500 m.

Standard Of Seats

Easy access to seats is highly valued. A certainty of 100% on trips longer than about 10 minutes is as important as a walking distance of less than 600 m.

Standard When Changing Buses

The attraction of the bicycle trip is twice as great when a change of buses is necessary, which is earlier rendered account for. This is a measure of the severe

effect which the bus changes have on the convenience. The total time of travel takes over this aspect.

Outline Of A Model

Share Of Locals	Maximum Real Walking Distance
2/3	400 m
1/3	600 m

- Total time of travelling, max 35 minutes.
- Bus frequency, not more than 10 minutes.
- Standard of seats, 100% certainty in trips longer than 10 minutes.

Example Of The Consequences Of The Model

If the walking distance in an outline exceeds 600 m the bus frequency should be reduced and possibly a longer total time of travelling be accepted to enable a reduced walking distance.

This weighing means e.g. that the route of a bus line cannot be direct and that there must be short distances between the bus stops in some parts of a town and thereafter great distances through the system of main routes.

Another consequence can be mentioned, namely that bus lines normally cannot be located in streets with satisfactory distance between buildings and noise.

Further Development

The total time of travelling and the standard of bus changes are the real strategic lines to work upon for the organization of town structures and region structures.

In the present stage 2 a comparative study of these parameters is planned in Stockholm, Malmö and a smaller town.

PARKING STRUCTURES IN THE CENTRAL PARTS OF TOWNS

The Hitherto Existing Basic View

The number of parking places per area within a certain traditional maximum walking distance or equivalent standards e.g. an increase of 100% of an existing street capacity have served as basis for the planning of central business districts.

The safety of the pedestrians and the cyclists has become a variable to this, depending on local conditions.

The demands for spatial directness for the vehicular traffic have furthermore grown considerably, which together with the above-mentioned achieved demand for capacity, have created situations where crossings are simply rejected because they are regarded as "impossible." Crossings with divided phases, with maximum waiting periods exceeding 60 seconds and with a proportioning walking speed of 1.2 m per second, which is almost twice as high as the "possible" speed, have been reported.

A New Basic View

When based upon knowledge about the facts about how pedestrians use different types of crossings in different types of traffic environments due to principally the circuit way required and/or delay of time, prognoses of the use of the outlined systems can be made.

When based upon knowledge about pedestrians' behavior of observation and car drivers' behavior of maneuvering further realistic criteria can be made.

When based upon risk figures an optimum of the traffic environments regarding safety can be made.

When based upon knowledge about the accepted distribution among classes of walking distance in environments with high standard of the public transport as well as with a decreased access to parking in every walking distance class, a location of parking places can be estimated with regard to the probable use. (From Report No. 4.)

Empirically founded demands for safety regarding pedestrians and cyclists are fundamental for the possible amount of parking and its possible location. The use of these parking places can be estimated and effected by a consciously selected standard regarding climate shelter in the pedestrian traffic system and by a complementary local bus line.

Outlines Of A Model

Share Of Parking Places	Maximum Real Walking Distance
1/3	L
1/3	2L
1/3	3L

When 3L exceeds 600-800 m a complementary local bus line is required.

Fundamental conditions: Defined minimum demands for pedestrian traffic and bicycle traffic regarding safety have been provided for.

LIST OF PUBLICATIONS

1. **Rapport:** "Intervjuundersökning av gående över Bazarbron och vid Näckrosdammen i Göteborg". 1964. Olof Lövmärk.
(Jämförelser av accepterade avstånd för olika ärendegrupper, åldersgrupper och kön i två strikt olika miljöer. Utdrag finns återgivna i meddelande nr 10 och 14).
2. **Rapport:** "Studie av den tidsmässiga variationen hos gångtrafiken över Kungäportsbron i Göteborg". 1964. Olof Lövmärk.
(Olika ärendegrupperns känslighet för nederbörd och kyla. Utdrag finns återgivet i meddelande nr 11).
3. **Rapport:** "Teori om gångtrafik och gångtrafikplanering". 1965. Olof Lövmärk.
(Definitioner av grundbegrepp och gångtrafikens egenskaper samt precisering av angelägna forskningsuppgifter).
4. **Rapport:** "Studie av gångtrafikens avståndsfördelning. Intervjuundersökning av gående till och från cityområdet i Göteborg". 1965. Olof Lövmärk.
(Utdrag finns publicerade i meddelande nr 10, 11 och 14. Speciell sammanfattning finns.)
5. **Program:** "Analys av gångtrafikanternas vägval". 1967. Olof Lövmärk.
(Program för studie nr 15).
6. **Program:** "Planstandard för gångtrafiksystem m a p bekvämlighet och säkerhet". 1968. Olof Lövmärk.
(Program för studierna nr 9, 16 och 17).
7. **Program:** "Riktlinjer för cykel- och mopedtrafik i innerstäder och centrumområden". 1969. Olof Lövmärk.
(Program för studierna nr 13 och 20).
8. **Program:** "Riktlinjer för busstrafiksystem i tätorter". 1969. Olof Lövmärk.
(Program för studie nr 19).
9. **Rapport:** "Lokalisering av övergångsställen". 1969. Sven Sivengård.
(Examensarbete, Institutionen för Trafikteknik, LTH).
10. **Uppsats:** "Med hänsyn till gångtrafik". 1969. Olof Lövmärk.
(PLAN nr 2 1969).
11. **Uppsats:** "Kollektivresenären som gångtrafikanter". 1969. Olof Lövmärk.
(SVENSK LOKALTRAFIK nr 2 1969).
12. **Uppsats:** "Att planera översiktligt för gåendes säkerhet". 1969. Olof Lövmärk.
(STADSBYGGNAD nr 2 1969).
13. **Föreläsning:** "Riktlinjer för cykel- och mopedtrafik i innerstäder och centrumområden". 1969. Olof Lövmärk.
(Föreläsning vid cykel- och mopedfrämjandets konferens. Ingår i konferensrapport).
14. **Rapport:** "Transportation Systems for Major Activity Centers. New approaches to Pedestrian Problems". 1969. Olof Lövmärk.
(Rapport och anförande vid OECD-konferens i Paris. Rapporten finns publicerad i OECD-rapporten "Transportation Systems for Major Activity Centers", 1970 samt i "Journal of Transport Economics and Policy", 1972).
15. **Rapport:** "Studie av effektiviteten hos separerade gångtrafiksystem". 1969. Olof Lövmärk. Ola Fogelberg.
16. **Rapport:** "Gångtrafiksystem i blandgator. Del 1: Studie av effektivitet och säkerhet". 1969. Olof Lövmärk, Klas Nydahl.
17. **Rapport:** "Riktlinjer för sanering av gångtrafiksystem i blandgator". 1969. Olof Lövmärk, Christer Hydén.
18. **Rapport:** "Förteckning över forskningsrapporter om gångtrafik". 1969.
(Förteckningen omfattar praktiskt taget samtliga studier som omnämnts i ledande internationell fackpress sedan 1960. Samtliga rapporter finns i PLANFOR's bibliotek. Upplysningar: forskningssekreterare Cecilia Svidén).
19. **Rapport:** "Attityder till kollektivt färdmedel. Intervjuundersökning i Malmö 1969". Lennart Svantemark, Anders Svidén.
(Examensarbete, Institutionen för Trafikteknik, LTH. Förstudie till nr 21 och 31).
20. **Rapport:** "Metod för optimering av hållplatssystem i cityområden. Effektivitetsstudier grundade på analyser av gångtrafik. Del 1: Teori". 1970. Olof Lövmärk.
21. **Program:** "Studier av busresenärers preferenser avseende olika bekvämlighetsfaktorer". 1970. Olof Lövmärk, Anders Svidén.
(Program för nr 31).
22. **Program:** "Metod för optimering av gångtrafiksystem och besökspunkters lokalisering m a p utnyttjande och bekvämlighet". 1970. Olof Lövmärk, Ola Fogelberg.
(Program för nr 30).
23. **Program:** "Metod för planering av blandtrafiksystem i innerstäder grundad på

- säkerhetskrav avseende gångtrafik". 1970. Olof Lövmemark, Klas Nydahl. (Program för del av nr 29).
24. **Program:** "Metod för planering av cykeltrafiksystem i innerstäder". 1970. Olof Lövmemark, Christer Hydén. (Program för del av nr 29).
 25. **Uppsats:** "Stadsbyggnadsforskning - om vad och hur?" 1971. Olof Lövmemark. (PLAN nr 4, 1971).
 26. **Rapport:** "Kvalitetskrav och planeringsmetodik avseende gångtrafik, cykeltrafik och kollektivtrafik." 1970. Olof Lövmemark. (PM utarbetad i anslutning till bedömning av prisämnesuppgift vid KKH, 1970).
 27. **Föreläsning:** "Gångtrafikmönster i innerstad". 1970. Olof Lövmemark. (Föreläsning vid fortbildningskurs i stadsbyggnad på temat Innerstad-Gångstad, KTH oktober 1970. Ingår i kursrapport. Finns i engelsk version).
 28. **Uppsats:** "Levnadskvalitet i stadsbyggandet." Olof Lövmemark. (STADSBYGGNAD nr 11 1971). **Lägesrapport:** "Utveckling av planeringsstrategi för trafiksystem i innerstäder och centra."
 29. **Lägesrapport:** "Utveckling av planeringsmetoder för trafiksänering. 1971.
 30. **Lägesrapport:** "Utveckling av planmodeller för bostadsstadsdelar." 1971.
 31. **Lägesrapport:** "Utveckling av planeringsmetoder för kollektiv trafik. 1971.
 32. **Anförande:** "Gångtrafiksystem och deras samverkan med övriga trafiksystem". 1971. Olof Lövmemark. (Sammandrag av anföranden vid konferenser på temat Närtrafik i Tårtor, arrangerade av Nordisk Komitté för Transportekonomisk Forskning, Århus 1970 samt Norrköping 1971).
 33. **Föreläsning:** "Levnadskvalitet i stadsbyggnaden. Utveckling av rationella planeringsmetoder avseende trafiksystem". Olof Lövmemark. (Föreläsning vid kursen "Trafikrummet" arrangerad av SAR, Lund 71. Ingår i kursrapport).
 34. **Föreläsning:** "Opbygning af byens trafiksystem IV: fodgaengersystemets udformning udfra trafikanter adfaerd og systemets funktioner". 1971. Olof Lövmemark. (Kursus i Bytrafikplanlægning. København 1971).
 35. **Databank, rapporter:** "Trafiksäkerhet för glände, cyklister och mopedister i Helsingborg". *Del 1:* Databank över gång- cykel- och mopedtrafikolyckor 1968 - 30.6.71. *Del 2:* Beskrivning av olycksstrukturer. Strategier för trafiksänering. Olof Lövmemark, Christer Hydén.
 36. **Databank, rapporter:** "Trafiksäkerhet för bilresenärer i Helsingborg". *Del 1:* Databank över bilresenärers personskador 1968 - 30.6.71. *Del 2:* Beskrivning av olycksstruktur. Strategier för trafiksänering. Olof Lövmemark, Christer Hydén.
 37. **Rapport, trafikant-anvisningar:** Metod för utveckling av trafiksäkerhetsanvisningar för speciellt utsatta grupper. Studie av personskador vid arbetsresor i Helsingborg 1968 - 30.6.71. Olof Lövmemark, Christer Hydén, Daniel Mellstedt.
 38. **Rapport:** "Studie av orsakssammenhang vid gång- cykel- och mopedtrafikolyckor i mest olycksbelastade gatutyp. Stenbocksgatan i Helsingborg 1969 - 70". Olof Lövmemark, Christer Hydén.
 39. **Databank, rapporter:** "Trafiksäkerhet för gående, cyklister och mopedister i Malmö". *Del 1:* Databank över gångtrafikolyckor 1968 - 70. *Del 2:* Databank över cykel- och mopedolyckor 1968 - 70. *Del 3:* Strategi för trafiksänering via informations- system grundad på analyser av olyckskoncentrationer samt attitydstudier. *Del 4:* Studier av risktal. Olof Lövmemark, Christer Hydén.
 40. **Rapport:** "Trafiksäkerhet för cyklister och mopedister i svenska städer. *Del 1:* Strategier för trafiksänering grundade på studier av risktal". Olof Lövmemark, Christer Hydén.
 41. **Rapport:** "Metod för erfarenhetsåterföring avseende trafiksäkerhet vid trafikreglering av stadskärnor. Utvecklingsstudier före och efter trafikregleringer i Lunds stadskärna 1971". Olof Lövmemark, Christer Hydén.
 42. **Rapport:** "Metoder för erfarenhetsåterföring avseende barns trafiksäkerhet i bostadsområden. Utvecklingsstudier i fyra småhusområden i Stockholm 1971 - 1972". Olof Lövmemark, Christer Hydén, Daniel Mellstedt.
 43. **Perspektivplan:** "Perspektivplan för Planforgruppens uppgift inom trafik- och stadsplaneringsforskning". 72/73 - 76/77. Olof Lövmemark.
 44. **Föreläsning:** "Sociala aspekter på framtidens samhällsbyggande. Levnadskvalitet och

trafiksystem". (Svenska Kommunal - Tekniska föreningens konferens i Stockholm 1972). Olof Lövmemark.

45. **Föreläsning:** "Du, trafikant, Planeringsstrategier, planeringsmetoder, system för erfarenhetsåterföring, forskningsteman". (Nyckel till Planförgruppens meddelandeserie). (Föreläsning vid kursen "Bostadens närmiljö"

arrangerad av SAR, Lund 1972). Olof Lövmemark.

46. **Generalprogram**

Förteckning över avslutade, pågående och planerade delstudier i TSU₇₂: Trafiksäkerhetsundersökning i Malmö av gång- cykel- och mopedtrafik för utveckling av trafiksaneringsprogram och översiktsplaner.

A Preliminary Proposal For Recommendations On Long Term Traffic Planning For Pedestrians Safety

SOME VIEWS BASED ON NEW RESEARCH RESULTS

Olof Lövmärk
Director, PLANFOR

A STRATEGY FOR LONG TERM RECOMMENDATIONS

It is a well established pedagogical fact that recommendations on planning principles and criteria are very hard to get accepted by planners and that once they are accepted new research results face an even more difficult position.

As the progress in town and traffic planning research probably will accelerate in the coming years, great care must be given this situation.

RESEARCH RESULTS THAT PERHAPS SHOULD NOT BE DISTRIBUTED

Present planning practice, principles and criteria, is characterized by

- Functionally unrealistic systems for new areas, low effectivity and high costs for segregated traffic systems, unobserved need for complimentary mixed links.
- Lack of strategy for regulation of traffic systems in central parts of towns, main safety problems are neglected or deteriorated by regulation.
- Lack of an over all strategy for all traffic safety activity in the community.

This situation, which seems international, can be explained by a research too focused on or chained to accident data. The renewal must first of all concern research.

A GENERAL METHOD FOR CREATING MORE ADVANCED PLANNING PRINCIPLES

Our research has reached a level which makes it possible to evaluate, directly and precisely by registration of behaviors traffic safety effects reached by regulation in central parts of towns and traffic safety standard in new areas.

Accidents for a couple of years, which normally are very confusing, are thus not needed to await.

This method gives a new foundation for developing rational planning principles and criteria.

The definitions of behavior and of traffic environments-traffic situations are founded on basic behavior studies related to accident data. The technique for registration, which must be of very high capacity, is electronic and computerbased.

PROPOSAL FOR CONTENTS IN THE REPORT

In our view a presentation of this new method for direct and precise evaluating of traffic safety will be of fundamental value for a long term developing of more advanced planning principles.

The method will be relevant regardless of traditional views on planning, traffic laws, economical aspects, motorization, size of town, district in town, category.

Proposal

- The report will generally describe this new method for all categories regarding
 - Regulation of existing traffic systems in central parts of towns.
 - Planning of new areas.
- The report will generally describe planning principles developed by hitherto accomplished behavior studies regarding an overall strategy for town and traffic planning with regard to traffic safety.

POSSIBLE CCMS RECOMMENDATIONS

- Centrally organized registrations of frequencies of safe, dangerous and accident preventing behaviors in combinations of traffic environment, traffic situations with high percentage of accidents. Central evaluation of principles and criteria.
- Local registration of number of travellers multiplied with frequencies reveals riskmasses.
- Local planning according to riskmasses and recommended principles and criteria from the central organization.
- International exchange of data.

PRACTICAL NOTES

PLANFOR is presenting this method and results from its use in two towns for National Boards and Councils in December 72. Reports in Swedish are

planned for January-March 73.

A presentation for CCMS before this seems hardly possible unless this is vital.

PLANFOR is acting as a private research institute in this cooperation with CCMS.

Traffic Safety In The Center Of Uppsala

Olof Löwemark
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PREFACE

In the work which has been carried out since 1971 within the Governmental Investigation into collective traffic in built-up areas (KOLT), attention also has been paid to certain questions of traffic safety. According to the directive of the investigation, it is of great importance that the aspects of traffic safety be observed when judging between collective and individual traffic.

In connection with the studies of various kinds which KOLT is undertaking in certain experimental localities in consultation with the municipalities concerned, investigations into traffic safety are also being pursued. Thus, KOLT - together with the City Council in Uppsala - has instructed the Research Group PLANFOR at the University of Lund to carry out studies of traffic safety in conjunction with the transposition of traffic which took place in the center of Uppsala in October 1972.

The method which the Research Group has adapted for studies of traffic safety in Uppsala had been developed with the assistance of research grants from the Transport Research Delegation, among others. The studies as now completed can be considered to be an adaptation of the method on a larger scale.

As the method is new and the studies in Uppsala illustrate its application in conjunction with the transposition of traffic, among other things, KOLT has deemed it of value that the result of the studies be now published. KOLT, not wishing in this connection to comment on the content of the report, intends to consider in its continued work how to make the method suitable for use in the planning of safety measures in municipalities when judging between collective and individual traffic.

The PLANFOR Group wishes to express its sincere gratitude to KOLT and the Uppsala City Council who have financed the extensive studies in Uppsala. In particular, we wish to thank the Civil Engineer, Bo

Stenman, and the Sociologist, Stig Hanno, of KOLT who initiated this adaptation of the Group's basic research relating to traffic safety.

This research was financed by the Transport Research Delegation.

The Civil Engineers, Leif Ringhagen and Tage Strand, worked with the Group.

SUMMARY

The report renders an account of a practical application of the method, developed by the PLANFOR Group, of determining travellers' risk of personal injury by the recording of behavior.

Previously, in order to determine the risk of travellers it was necessary to resort to analyzing the traffic accidents that had occurred.

The greatest advantage of the method of recording behavior is that it gives an immediate and precise description of the risk of travellers which is of great importance, for example by assessing the safety effects of a traffic regulation. For a comparable evaluation by means of accident data at least two years' accident material is required.

The principle of the method is that the risk of personal injury, to which travellers are exposed, is in direct proportion to the number of serious conflict situations, in which travellers in a flow are involved.

Serious conflict situations arise as a consequence of either an uncontrolled conflict-averting behavior or a dangerous traffic behavior which produces an uncontrollable situation. In both cases the travellers involved must pass one another at a distance of less than about 1m, partly due to the means of conveyance and the type of traffic environment. The risk of personal injury varies according to the type of traffic environment, the traffic situation, the means of conveyance (conflict class) and the volume of vehicle flow creating the conflict.

The amount of risk, which is a measure of the probability of an accident causing personal injury occurring, can be estimated only on the knowledge of the volume of the flow of travellers and the risk of personal injury in the existing classes of conflict.

The recording of the travellers' behavior and serious conflict situations is made by direct observation. To achieve a uniform interpretation of

the chosen definitions a preceding training period is required for the observers as are control studies carried out both before and during the recording. The recording of the travellers' behavior is made by an electronic measuring device. The evaluation is based on computer data.

In the report an account is rendered of an application of the method, partly in order to assess the safety effects of the traffic regulation introduced in the center of Uppsala on the 1st October 1972, and partly to produce the first stage in the building of a general behavior data bank which is to be the basis of the development of a municipal program of measures against traffic accidents.

Through this method, planning can be based on a precise description of the present risk, amount of risk, probable alteration of these and the drawing up of a precisely defined aim in respect of traffic safety.

The evaluation of the effect of the Uppsala Regulation showed that traffic safety improved somewhat in respect of all means of conveyance because of measures that were taken in those routes where the traffic was increased owing to the regulation.

The total reduction in risk of the Uppsala regulation was:

Pedestrian traffic	5%
Cycle traffic	2%
Car traffic	11%
Total means of conveyance	5%

BACKGROUND

In order to assess the safety effects of the traffic regulation it was necessary previously to observe traffic accidents.

In order to obtain a characteristic survey of the accident structure in a regulation zone probably about two years' traffic accidents were required. A characteristic accident structure for an individual traffic locality may require about double this period of time.

Further, analyses of police reports of personal injury show a limited potential for determining the causal connection of the traffic environment with the occurrence of the injury.

These circumstances have obviously had a paralyzing effect on the development within traffic and town planning with regard to traffic safety which can be illustrated by the following example.

- Development of rational principles for traffic regulation with an effective working out of detail

to prevent traffic accidents could not be based on the precise description of risks.

- Municipal traffic regulation plans could not be based on a precise description of the amount of risk in the present traffic system, nor could same be assessed in respect to the likely alteration of these amounts of risk. Thus, they could not be based on precisely defined political aims concerning high traffic safety.
- Municipal survey plans could not be based on precisely defined aims regarding traffic safety, nor forecasts of altered amounts of risk. This applies to plans for the center, parking plans, and traffic route plans for the inner town which are of decisive importance for traffic safety.

AIM

The illustration of the strategic research task of developing a method for the immediate and precise determination of risks and amounts of risk by data-behavior can be made more comprehensive. In order to describe the total extent of the importance of such a method we would state that political aims in respect of traffic safety can consciously be formulated and can be made the basis for all traffic and town planning, both in an existing town and when planning a new town, both short-term planning and long-term town planning.

The Group's basic research, started in 1968, aims at solving this strategic research task. So far the work has encompassed the following stages:

- Development of a system for local accident data banks of personal injury reported by the police and environmental data, as well as methods of analyzing these data banks.
- Precise description of the accident structure according to these systems and methods by practical application.
- Studies of the causal connection of traffic accidents in selected types of traffic environment by means of verbatim report of examination of the travellers and witnesses involved.
- Studies of the existing behavior in the types of traffic environment and traffic situations with a high accident proportion.
- Studies of dangerous traffic behavior and accident-causing behavior, as well as serious conflict situations in selected types of traffic environment and traffic situations.
- Experimental description through studies of behavior of changed risks and amounts of risk at the traffic regulation in the center of Lund 1971.

- Development of a method of electronic recording of traveller behavior and direct data analysis.

The aim of the studies in Uppsala was to apply the method, developed as stated above, of describing risk by means of behavior data. The risk or amounts of risk for precisely defined combinations of the type of traffic environment - traffic situation - means of conveyance and the volume of the conflict-producing flow of vehicles are indicated in proportions of the respective number of travellers who are involved in serious conflict situations.

SUMMARY OF RECORDING RESULTS

About 30,000 traveller journeys in Uppsala have been behavior-recorded and analyzed. Parallel extensive calculations of the number of travellers have been made.

The evaluation of the effects of the regulation has produced the following values for the total reduction in risk amount in the regulation zone:

Risk amount

Pedestrian traffic	reduction	-	5%
Cycle traffic	reduction	-	2%
Car traffic	reduction	-	11%
Total means of conveyance	reduction	-	5%

Thus, the Uppsala regulation has clearly reduced the total amounts of risk.

The principle of the regulation was to force the traffic flow of cars from the center of the town to surrounding routes. Even before the regulation these had on an average about twice as large a traffic flow of cars (11,000 cars/24 hrs. average annually) in comparison with the streets within the regulation zone (5000). By means of the regulation the amount of car traffic on the surrounding routes has been increased by an average of 30% (to 14,000) and in the streets within the zone it has been reduced by an average of about 40% (to 3000).

As in general the risks are greatly influenced by the amount of car traffic, this principle of regulation presupposes that to avoid producing serious negative total results the traffic spacing in the surrounding routes be systematically made less complicated by means of supplementary regulations. In the traffic regulation which has so far been introduced in Sweden in the various districts, apart from the Uppsala regulation, this strategic supplementary regulation in the routes which have to carry increased traffic has not been followed.

In spite of the supplementary regulations introduced in the surrounding routes in Uppsala the amounts of risk in these routes have been increased as

a consequence of the regulation:

Pedestrian traffic	increase in the amount of risk	+	12%
Cycle traffic	increase in the amount of risk	+	9%
Car traffic	increase in the amount of risk	+	4%
Total means of conveyance	increase in the amount of risk	+	8%

In the streets within the regulation zone the risks have been reduced as follows:

Pedestrian traffic	risk amount decrease	-	29%
Cycle traffic	risk amount decrease	-	47%
Car traffic	risk amount decrease	-	67%
Total means of conveyance	risk amount decrease	-	46%

The studies completed in Uppsala produce a precise basis for planning of continued supplementary regulation, the effects of which can be forecast. The studies also produce a basis for a conscious long-term planning from the point of view of traffic safety of the center and the system of main routes in the inner town.

The relations of the behavior data to the research result in respect to accident data which have so far been carried out have shown a good conformity. These relations are to be continued, among other things, by means of the international research result in respect to risk figure through accident data, and by statistical relation of the behavior data bank to the local accident data bank. The result of the evaluation in Uppsala gives occasion to draw hypothetically the following strategic conclusion:

If a reduction in the risk amount in the order of magnitude 1/3 (about 6 times the Uppsala effect) is set as the target for the inner town, where at present there are more than half of the total amounts of risk, then such extensive and safe signal regulation on main arteries must be introduced that this would jam the daily amount of car traffic in the peak periods.

This hypothetical conclusion appears likely to apply to towns of up to 100,000 population at the present volume of cars. It should therefore apply to smaller towns when the density of cars will be higher than is the case at present.

This problem of balancing traffic safety as against car traffic and thus the collective traffic's quantitative object would appear to be a reality for medium size towns in the near future.

It is the hope of the Group that by means of the method developed and an extended behavior data bank they may contribute in achieving the illustration of this strategic balancing problem.

DESCRIPTION OF METHODS

We merely intend to give below a brief description. For a precise mathematical formulation we would refer to PLANFOR Information Pamphlet No. 59. In Information Pamphlet No. 60 an account is rendered of the organization of the behavior data bank and its present range. In Information Pamphlet No. 61 an account is rendered of methods for statistical control of the reliability of the behavior data bank and the analyses so far carried out. (Information Pamphlets Nos. 59, 60 and 61 are appearing in the Spring of 1973.)

DEFINITION OF THE BASIC PRINCIPLE

The basis of the method is that risk of personal injury (R) can be described as the proportion of travellers in a flow of travellers (T) who are involved in conflict situations of a serious type (KS), i.e.

$$R = \frac{TKS}{T}$$

The risk of personal injury varies according to the type of traffic environment (M), traffic situation (S), means of conveyance (F) = classes of conflict. Conflict classes with a significant risk of personal injury have been separated off by basic analyses of accident data - among others local accident data banks. Within each conflict class the risk of personal injury varies with the order of magnitude of the conflict-producing vehicle flow.

The selection of conflict-averting behavior and dangerous traffic behavior has been based partly on studies of causal connection in traffic accidents, and partly on the basic studies of behavior.

CONFLICT-AVERTING BEHAVIOR:

Car travellers:	Violent braking or swerving. Rapid acceleration.
Cycle travellers:	Violent braking or swerving. Rapid acceleration.
Pedestrian travellers:	Abrupt crossing or retreat.

DANGEROUS TRAFFIC BEHAVIOR:

Car travellers:	Failing to brake before a crossing. Overtaking another car immediately before an indicated crossing. Careless driving.
Cycle travellers:	Failing to brake before crossing. Failing to give a signal before proceeding in file. Careless cycling.
Pedestrian travellers:	Not looking before walking on to the roadway. Looking but walking on to the roadway in spite of an approaching vehicle. Careless walking.

Conformity between accident data and behavior data is dependent upon the degree of seriousness that characterizes the conflict situations which are utilized when calculating risks.

Finally, the selection of definitions of the degree of seriousness of the conflict situations was made after a test of the results obtained in respect to the risk figure's distribution within and among the conflict classes. These definitions agree in principle with an English study of car travellers' risk measured in behavior. (A pilot study of traffic conflicts at a rural dual carriageway intersection. B. R. Spicer, Road Research Laboratory.)

The following definitions were selected: A conflict situation is serious when it is caused by either:

- An uncontrolled conflict-averting behavior which results in a situation where the travellers are passing or standing close by one another.
- A dangerous traffic behavior which results in an uncontrollable situation where the travellers are passing close by one another.

The risk amount (RM) of a flow of travellers is a measure of the probability that some traveller in the flow will be involved in an accident resulting in personal injury. The amount of risk is calculated by multiplying the number of travellers in the flow studied (T) by the risk (R) for the conflict class concerned at the actual volume of the conflict-producing flow of vehicles, i.e. $RM = R \times T$. This means that for a description of risk amounts only quantitative calculations are required if behavior data are recorded for the conflict classes concerned.

A summary of each means of conveyance can be made of the calculated flow risk amounts which means that the risk amounts for each means of conveyance can be obtained in respect of each square, street, part of a district or for the whole area studied.

Differing maneuvering prerequisites for the different means of conveyance implies that the risk amount defined as serious conflict situations has differing relation to the corresponding number of accidents.

The relation figure (r) between these can be calculated by relating the risk amount to the number of accidents per means of conveyance. Thus, the risk amounts for the various means of conveyance can be equated, i.e.

$$RM^{II} = r \times RM^I$$

where

II refers to the converted comparable risk amount

I refers to previously calculated risk amount

r relation figure per means of travel

The calculation of the relation figures for the Uppsala study are shown later in this section.

RELIABILITY

The reliability of the method of describing risk by behavior data can be systematically analyzed by relating the behavior data to the accident data, whereby a directive is obtained for the continued build-up of the data bank.

The behavior data bank which the recordings in Uppsala produced has been controlled by being related to risk figures obtained by studying accident data and to the proportion of accidents according to local accident data banks.

Before continued extension of the behavior data bank it must all be related to the local accident data banks organized in conflict classes corresponding to the behavior data bank. Order of precedence between traffic locations is also to be established.

METHOD OF RECORDING

For the recording of conflict-averting behavior, dangerous traffic behavior and serious conflict situations an electronic measuring device is used consisting of a portable tape recorder with key set for electronic recording on cassette tape. At each study only one flow is observed and the number of conflict-averting behavior, dangerous traffic behavior and serious conflict situations between travellers in this flow and all flows of vehicles producing conflict

are recorded. For each traveller in the selected flow a sequence of recordings is made involving between 7 and 15 recordings by means of the key set.

METHOD OF EVALUATION

The cassette tape is converted to punched tape for processing by computer according to a previously developed standard program.

The transcription of the result enables the following evaluations:

- The number of travellers in the primary flow studied.
- The proportion and number of travellers in the primary flow characterized by either a traveller in the primary flow or in some conflict-producing vehicle flow showing dangerous traffic behavior and the conflict-producing vehicle flow that is involved.
- The proportion and number of travellers in the primary flow characterized by any traveller involved showing an accident-averting behavior and the conflict-producing vehicle flow involved.
- The proportion and number of travellers in the primary flow characterized by being in a serious conflict situation and the conflict-producing vehicle flow involved.
- The proportion and number of travellers in the primary flow characterized by a traveller showing dangerous traffic behavior which causes a serious conflict situation and the conflict-producing vehicle flow involved.

LAY-OUT OF THE INVESTIGATION

Determination of Risk

For each selected conflict class behavior recording was made in at least two instances, one before and one after the traffic regulation. For certain conflict classes several studies were carried out, either at the same traffic locality or in different traffic localities. The object of this was to obtain more precise knowledge of these conflict classes in respect to the variation of risk according to the volume of the conflict-producing vehicles. Each study comprised two hours' observations, either during the morning peak-hour traffic, midday or afternoon.

For each study the actual amount of conflict-producing vehicles was determined by means of traffic calculations. The behavior-recording was carried out in respect of about 50 selected primary flows.

RISK AMOUNT DETERMINATION

Each pedestrian or cycle traffic flow of importance within the traffic regulation area was recorded during the morning and afternoon peak-hour once before the regulation in September 1972. These two hours were added. In view of the fact that the recordings of pedestrian and cycle traffic flows, which were made in conjunction with the behavior recordings, did not show any significant redistribution of the pedestrian or cycle traffic after the regulation, the same values of the pedestrian and cycle traffic were used before and after the regulation. As the pedestrian and cycle traffic in September correspond to the average value in respect to the annual variation, a whole year's risk amounts could be determined both before and after the traffic regulation.

For the calculation of the volume of substantial car traffic flow recordings that were made by the City Council both before and after the traffic regulation were used the total of the morning and afternoon peak-hour was calculated. In the same manner the volume of each conflict-producing vehicle flow was calculated.

THE TRAFFIC REGULATION IN THE CENTER OF UPPSALA

The object of the regulation was to reduce the car traffic in the inner town, thereby improving the conditions for the collective traffic and the unprotected travellers in that area. Traffic through the center and direct traffic between the various parts of the center was prevented, being directed to surrounding routes and certain connecting routes in the center.

In order to achieve this, one-way traffic was used, no turning, and motor vehicle traffic prohibited. On certain one-way streets two-way bus and cycle traffic was permitted.

RESULT REPORT

The risk amount before and after the traffic regulation is indicated below in tables and diagram for each traffic locality, means of conveyance and total.

In the tables the type of traffic environment before and after the regulation is also indicated.

Codes for the Type of Traffic Environment

Figure 1:

1. Uncontrolled crossing (right-hand rule)
2. Crossing with priority right of way
3. Crossing with a halt sign
4. Signal controlled crossing without separate green phase for the flow turning left (vsv)
5. Signal controlled crossing with separate green phase for part flow turning left
6. Ditto for all flows turning left.

Figure 2:

1. 3-way crossing, all streets 2-lanes
2. 3-way crossing, all streets 4-lanes
3. 3-way crossing, one or two streets 2-lanes and two or one streets 4-lanes
4. 4-way crossing, all streets 2-lanes
5. 4-way crossing, all streets 4-lanes
6. 4-way crossing, two streets 2-lanes and 2 streets 4-lanes
7. Pedestrian and/or cycle path crossing 2-lane street
8. Pedestrian and/or cycle path crossing 4-lane street

Figure 3:

1. No zebra-crossing (os), no one-way street (or)
2. No zebra-crossing, some one-way streets
3. No zebra-crossing, all one-way streets
4. os in some streets, no streets (or)
5. os in some streets, some streets (or)
6. os in some streets, all streets (or)
7. os in all streets, no streets (or)
8. os in all streets, some streets (or)
9. os in all streets, all streets (or)

Locality No.	Street name	Type of traffic environment		Behaviour Study made on category	Risk amounts - Results								Remarks
		Before	After		Before			After					
					Ped.	Cycle	Car	Tot.	Ped.	Cycle	Car	Tot.	
1	Kungälv. - Skövde.	467	467	C,B	4	20	15	39	6	25	25	56	
2	Kungälv. - Linnä.	264	265	C	4			4	6			6	
3													
4	Kungälv. - Sitt Ölofag.	454	454	B,C,C	11	66	30	127	19	124	51	194	
5	Kungälv. - Lotters	181	181	C,C	10	7		17	17	10		27	
6													
7	Kungälv. - Porag.	464	464	C,C	7	31	17	55	3	31	13	47	
8	Kungälv. mellan Vekrelag, och Sitt Porag.	181	181	C									
9	Kungälv. - Vekrelag.	465	465	C,C,B	25	63	58	146	27	66	33	126	
11	Kungälv. mellan Vekrelag, och Brodgränd	484	484	C	48			43	61			61	
12	Kungälv. - Bergaredag.	467	367	C,B,C	11	49	51	111	8	22	40	82	
13	Kungälv. (mellan Bergaredag, och Biveras	184	184	C	28			28	40			40	
14													
15	Kungälv. - Biveras grand	465	465	C,C	3	5	16	24	2	3	17	22	
16	Kungälv. - Bettungag	231	231		4			4	8			8	

FIGURE 1

Locality No.	Street name	Type of traffic environment		Behaviour Study made on category	Risk amounts - Results								Remarks	
		Before	After		Before				After					
					Ped.	Cycle	Car	Tot.	Ped.	Cycle	Car	Tot.		
17	Kungälv - Hamneplanen	231	231		3			3	5				5	
18	Kungälv - Strandbodg.	457	457	G, C, B	4	99	50	153	7	155	91	277		
19	Dreggerbrunnag - Strandbodg.	134	135	C	4	16	20	40	7	7	18	32		
20	Strandbodg. - Kungälvings	164	165	C, B	6	16	10	32	6	52	9	69		
21	Hamneplanen - Kungälvings	144	145	G, C	3	21	6	30	3	8	9	20		
22	Hamneplanen - O. Agatan	212	212		6	45	13	64	9	66	18	93		
23	Ostra Agatan - Boverne gränd	145	145	G, C	26	136	95	257	27	72	34	133		
24	Islandsbron - Västra Agatan	145	145	G, C	31	41	27	99	34	74	40	151		
25	Munkg. - mellan Trädgårds- och V. Agatan	181	181	G	13			13	16			16		
26	Munkg. - mellan Trädgårds- och N. Slottag	181	181	G	10			10	11			11		
27	Munkg. - Nedre Slottag.	137	137	G, C, B	21	95	55	171	32	120	89	245		
28	Nedre Slottag - Slottagrand	111	111	G, C	2	2		5	4	2		6		
29, 30	Nedre Slottag - Drottningg.	345	345	G, C, B	2	38	14	56	4	35	57	57		
31														
32	Ostra Slottag - Drottningg.	214	214	G, C, B	30	68	78	172	32	43	66	146		
33														

FIGURE 2

Locality No.	Street Name	Type of traffic environment		Behaviour Study made on category	Risk amounts - Results								Remarks
		Before	After		Before				After				
					Ped.	Cycle	Car	Tot.	Ped.	Cycle	Car	Tot.	
34	O. Stotveg - Angrand	244	245	C, C	10	31	22	63	13	43	31	88	
35													
36	O. Stotveg - Grop-grand	214	215	G, B	8	24	9	41	11	38	10	58	
37	O. Stotveg - Sit Olofveg.	144	145	G, C, B	18	67	71	156	18	88	47	156	
38													
39	Sit Olofveg. - Kyrkogårdsgatan	134	136	C, G	6	67		73	4	22		26	
40	Kyrkogårdsg. - Sit Johannev.	157	158	C, C	11	57	53	121	12	52	60	131	
41	Skolg. - Kyrkogårdsg.	134	134	G, C	1	37	53	93	1	85	102	188	
42	Skolg. - Stotveg.	115	115	G	2	2	7	11	6	2	11	19	
43	Skolg. - Rändels grand	244	244	G, C, B	3	15	9	27	6	24	17	47	
44	Skolg. - mellan Kyrkogårdsg. och Stotveg.	171	171	C									
45	Skolg. - Sit lareg.	232	171	G, C	4	3		7	10	7		17	
46	Skolg. - Sydölmareg.	467	467	G, C, B	18	49	18	85	18	77	22	117	
47	Skolg. - mellan Sydölmareg., Stureg. o. Ölog.	181	181	G	15			15	21			21	
48	Skolg. - V. Stureg.	261	261		6	82	22	110	9	118	40	167	
49	Skolg. - Sönderbackveg.	452	452	G, C	8	57	18	75	2	50	23	84	

FIGURE 3

Locality No.	Street name	Type of traffic environment		Behaviour Study made on category	Risk amounts - Results								Remarks	
		Before	After		Before				After					
					Before				After					
					Ped.	Cycle	Car	Tot.	Ped.	Cycle	Car	Tot.		
50	Sit Johannesg. - Sit Lärsg.	143	143	C		2		2					0	
52	Sit Johannesg. - Sydströmssg.	105	105	G, C	8	5	9	22	9	5	4	18		
54	Sit Olofsg. - Sit Lärsg.	242	243	C	2	10		12	1	7		8		
55	Sit Olofsg. - Sydströmssg.	467	466	G, C, B	12	75	19	106	13	99	15	180		
56	Sit Olofsg. mellan Sydströmssg. o O. Ag.	187	187	G, C	6	22		28	6	25		37		
57	Sit Olofsg. - O. Agsten	162	162	G, C	16	160	65	243	81	132	26	181		
58	Sit Olofsg. - Svertholmsg.	437	437	G, C, B	13	60	31	124	4	26	27	57		
59	Sit Olofsg. - Brägarbrunnsg.	264	264	G, C, B	13	26	21	60	15	26	26	74		
60	O. Agsten mellan Sit Persg. och Sit Olofsg.	173	273	G	32			32	21			21		
61	O. Agsten - Nybren	162	162	G, C, B	81	46	32	169	44	31	18	99		
62	V. Agsten - Nybren	162	162	G, C, B	17	42	13	72	24	13	5	42		
63	Drottningg. mellan V. Ag. och Trädgårdsg.	176	176	G	21			21	12			12		
64	Drottningg. mellan O. Agsten och Skottstorg	174	174	G	3			3	3			3		
65	Skottstorg - Trädgårdsg.	142	143	B		5	2	7		5	4	9		

FIGURE 4

Locality No.	Street name	Type of traffic environment		Behaviour Study made on category	Risk amounts - Results								Remarks	
		Before	After		Before				After					
					Ped.	Cycle	Car	Tot.	Ped.	Cycle	Car	Tot.		
66	C. Agatan mellan Bre/strand o Drottningg.	215	215	C	40				49	23			23	
67	Benderlag - O. Agatan	114	115	G, C, B	6	82	75	163	5	72	22	99		
68	Benderlag - Kungälvsg.	115	215	G	33	11	24	73	79		7	41		
69	Benderlag - Dregerbrunnsg.	241	242	G, C	30	14	51	135	18	21	23	62		
70	Linneg. - Svanöcksg.	112	113	C		11	2	13		5	1	6		
71	Svanöcksg. mellan Linneg. o Sit	123	123	G					1			1		
72	Olofsg.													
73	Odinuland - Bickopsg.	141	171	G	3	20		23	1	5		3		
74	Kungälvsg. - Baverns grand	142	142	G	8	20	49	41	1	5		6		
75	Sit Johannesg. - O.	142	141	G		13	3	5		2		2		
76	Slottsg.													
77	O. Agatan - Dombro	142	242	C		33	3	36		24		24		
78	Kungälvsg. - Kallin-garand	143	143	C	2	7	12	21	1	5	4	10		
79	Bredstrunnsg. Baverns grand	143	143	C, B	1	5	9	15		3	3	6		
80	Bredstrunnsg. Vekasg.													
81		441	441	C		9	6	13						

FIGURE 5

Locality No.	Street name	Type of traffic environment		Behaviour Study made on category	Risk amounts - Results								Remarks
		Before	After		Before				After				
					Ped.	Cycle	Car	Tot.	Ped.	Cycle	Car	Tot.	
82	Draegbrunnag. mellem Veikvang. o Sit Perag.	174	174	C	7			7	3			3	
83	Draegbrunnag. mellem Veikvang. o Bredgrand	174	174	C	7			7	4			4	
84	Draegbrunnag. mellem Banderdeg. o Bredgrand	174	174	G	17			17	9			9	
85	Draegbrunnag. mellem Sit Perag. o Klosterag.	171	171	G	37	37	14	88	9	9		18	
86	Draegbrunnag. mellem Klosterag. o Sit Okofag.	174	174	G	3			3	4			4	
87													
88	Fyris torg - V. Agsten	173	173	G		5	5	6		2		2	
					853	2107	1246	4202	611	2076	111	3098	

FIGURE 6

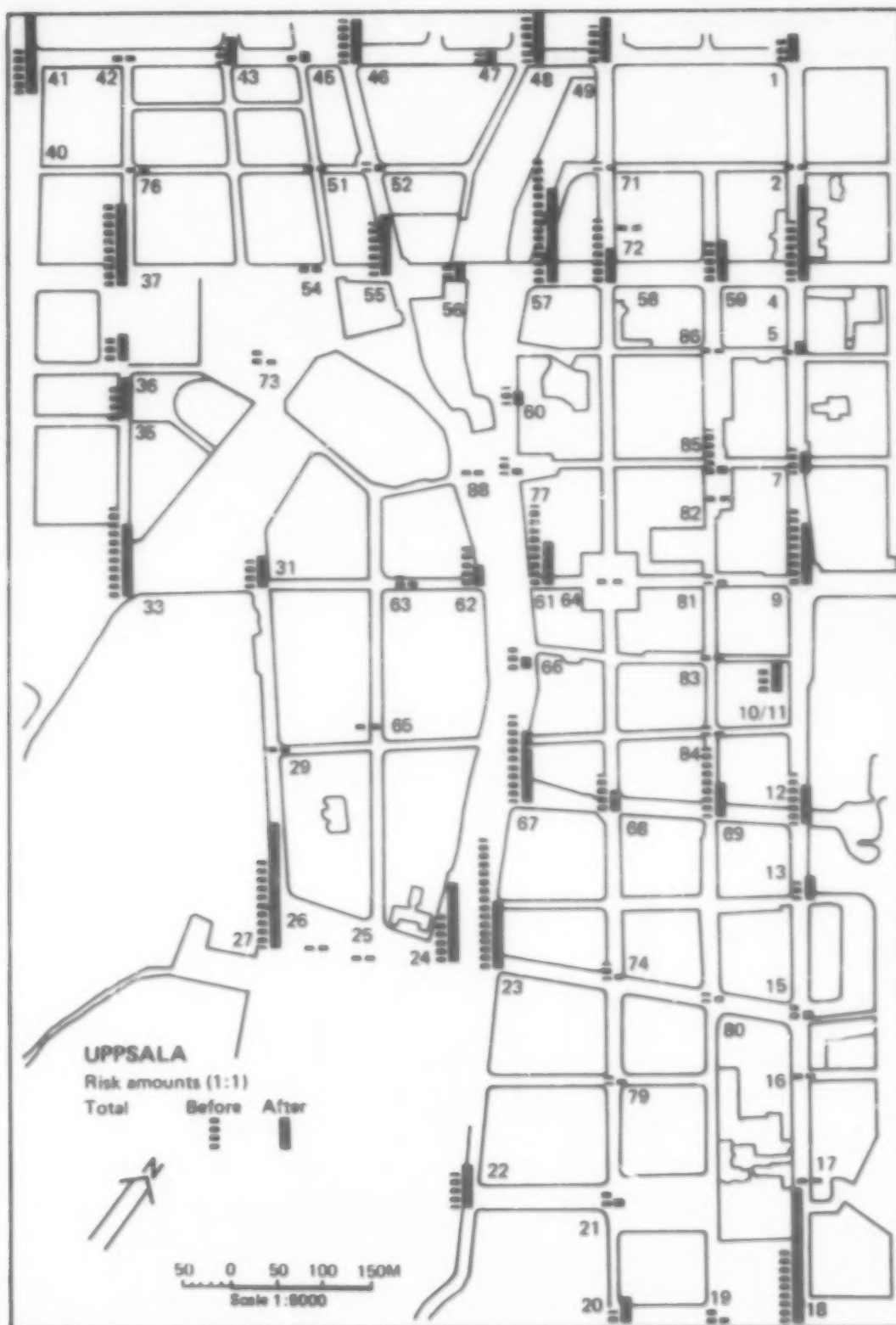


FIGURE 7

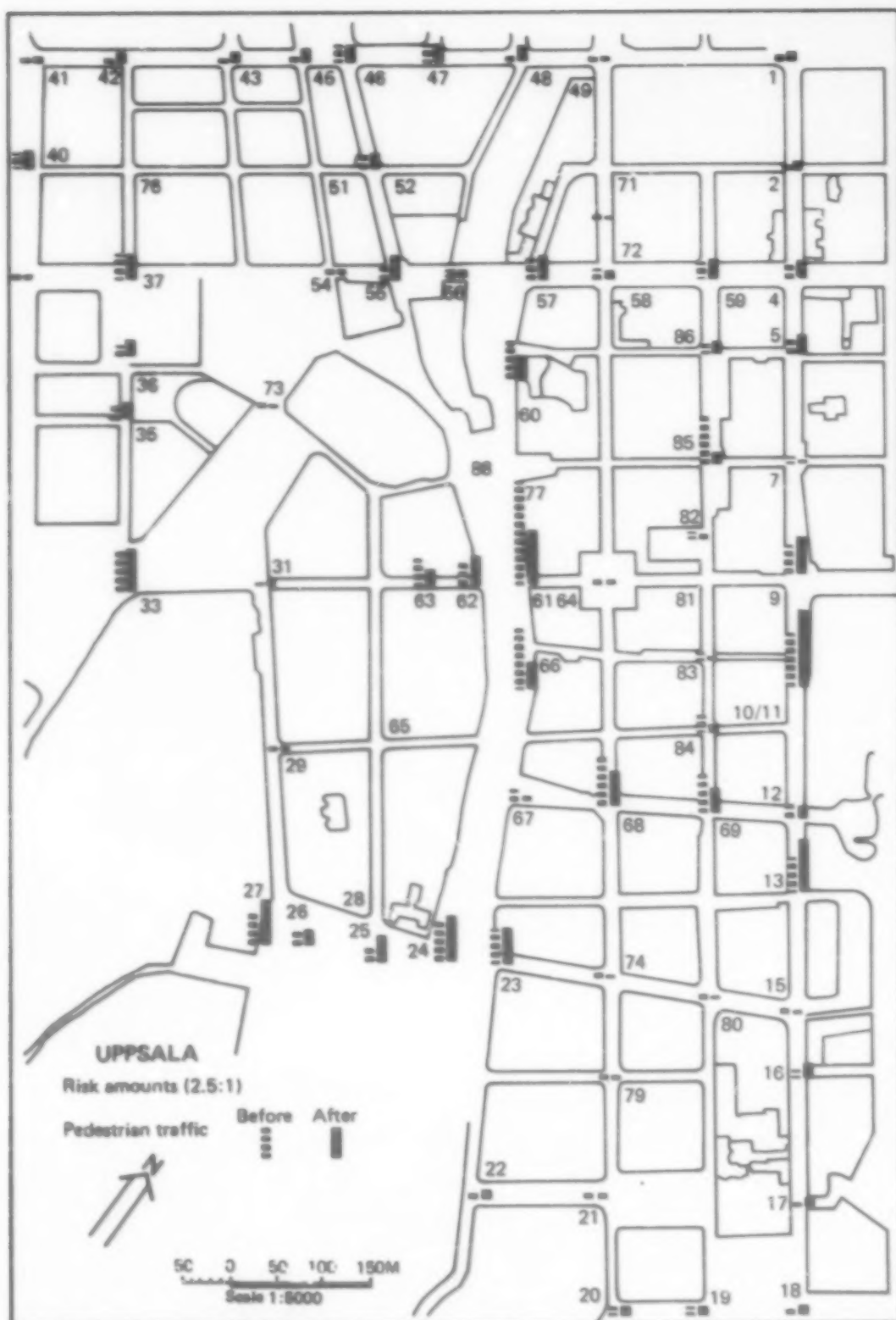


FIGURE 8

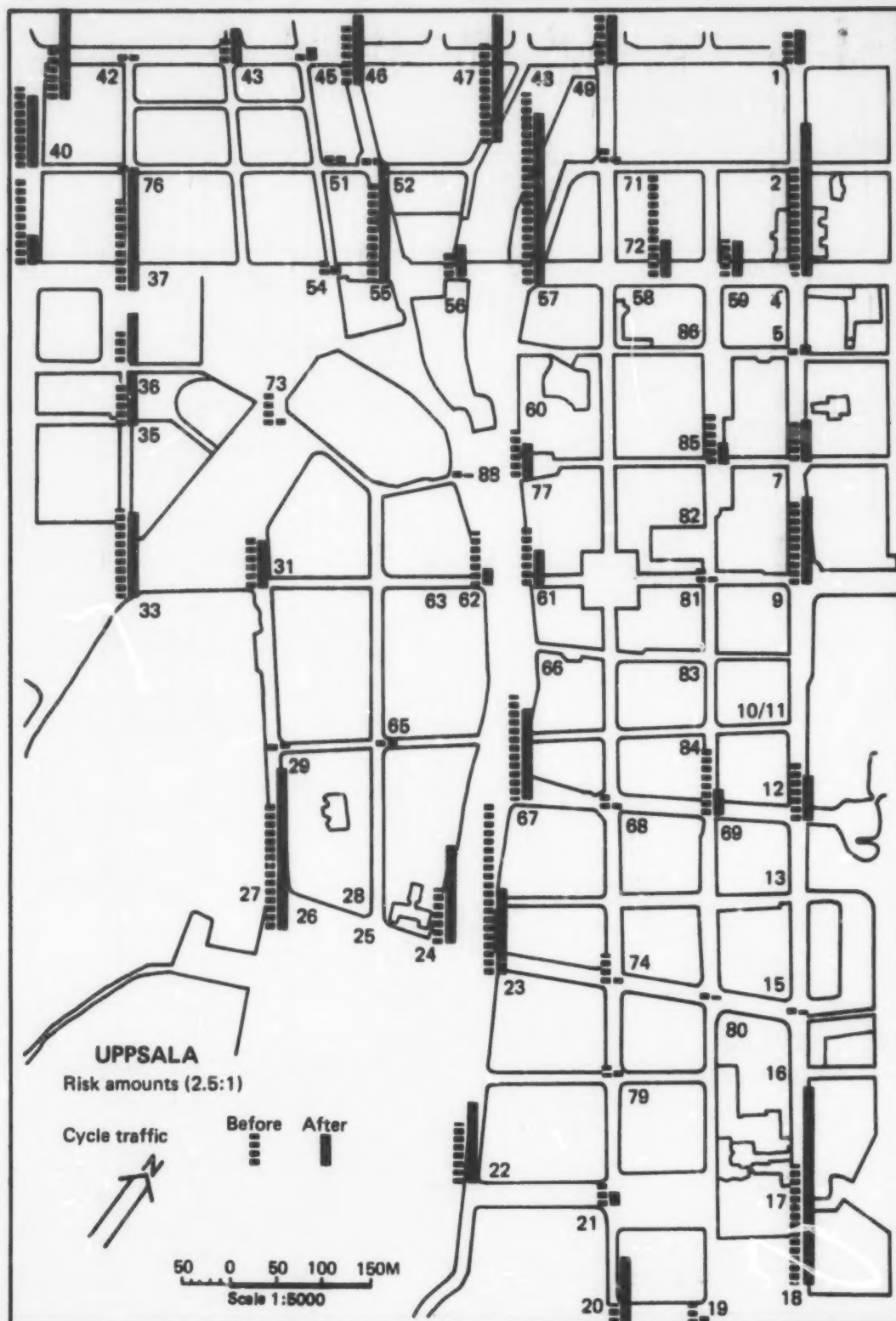


FIGURE 9

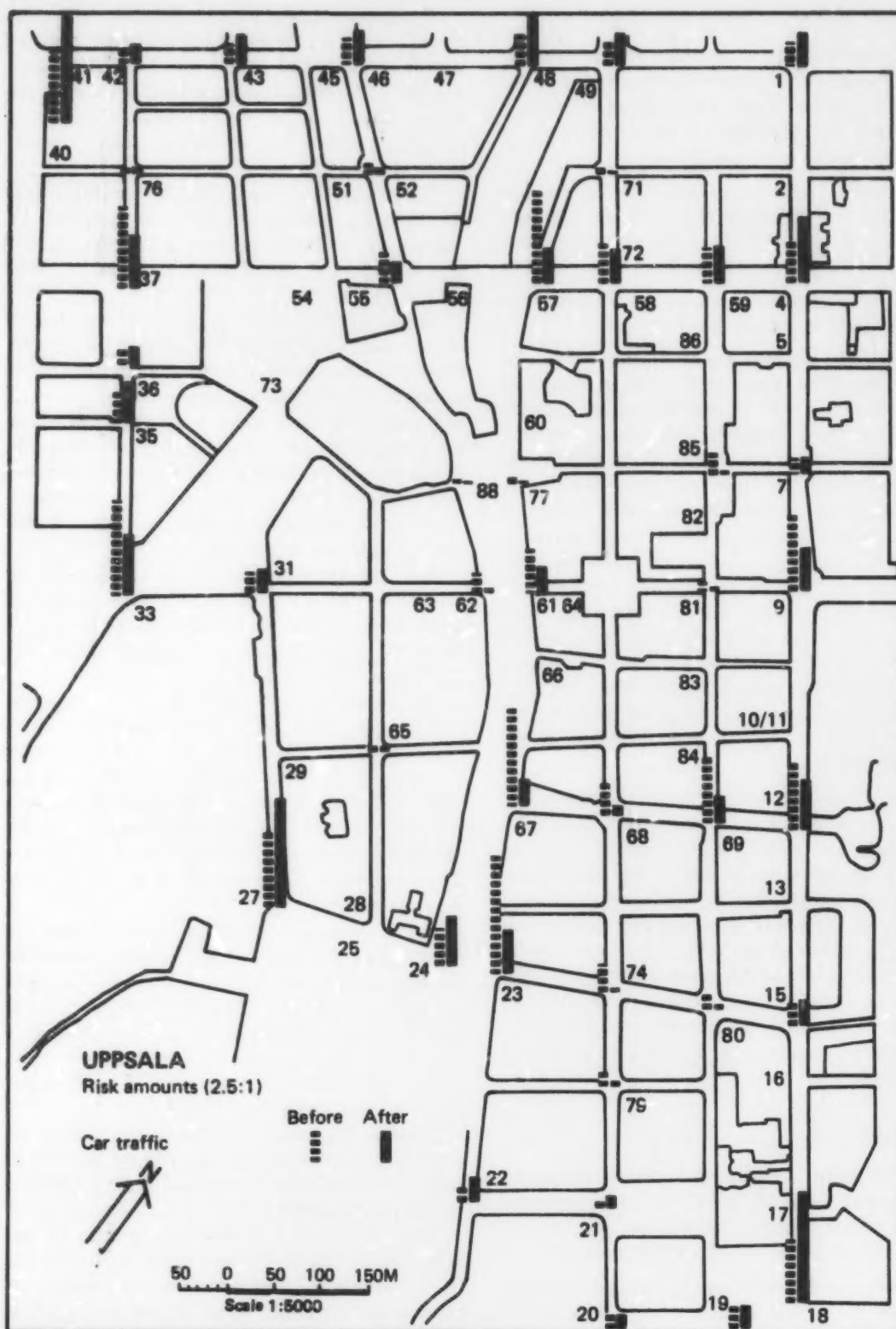


FIGURE 10

METHODS FOR PRACTICAL APPLICATION

In general the value of the study is that a behavior bank is built up and, obviously, the fact that the method so far has shown a reliable result. Thus, a conscious traffic planning can be introduced with regard to traffic safety.

Locally, for Uppsala the value of the study is that a basis for a continued traffic regulation has been obtained and also that the total effect has been recorded of the regulation introduced.

For the continued planning in Uppsala the following analyses can now be carried out:

- Greater risk amounts per traffic locality can be separated off by means of the tables and diagrams completed, as well as specially exposed traffic flows in these localities. For these flows the distribution into the various dangerous traffic behavior can be made and thus appropriate regulations introduced. The degree of suitability of these regulations can be systematically described by the priority figure: maximum reduction of risk amount per cost of the regulation or reduced capacity for car traffic. Thus, a running optimum program of measures against traffic accidents can be established based on the political aim in respect to traffic safety and passage for car traffic. (The latter points presuppose access to the computer data which should be made available to the Municipalities.)
- A basis has also been obtained for the future planning in respect to the center of the town, for example with regard to the number of parking spaces in the center in view of the political aim regarding traffic safety. These forecasts of altered safety on account of changed traffic environment and the volume of car traffic presuppose access to the risk diagram of the behavior data bank. (This must be placed at the disposal of the Municipality when the data bank has been processed.) Probably, certain supplements to the data bank will be required.

SUMMARY

In this report is presented a practical application of a method to decide travellers' risks of personal injuries through behavior registration. This method has been developed by the PLANFOR group.

Earlier it was necessary to analyze occurred accidents to be able to describe the risks run by travellers.

The great advantage with the behavior registration method is the immediate and precise description of travellers' risks which it can give. This is of great importance for the summing up of, for example, the safety effects of a traffic regulation. For a comparable summing up through accident data, there is a need for at least 2 years' accidents.

The fundamental thing about the method is that the risk for personal injuries that travellers are exposed to is directly proportional to the share of serious conflict situations which travellers in a flow are involved in.

Serious conflict situations result from, either an uncontrollable conflict-averting behavior, or a traffic dangerous behavior which provokes an uncontrollable situation. In both cases the involved travellers should pass each other at a distance less than one meter partly depending on means of conveyance and traffic environment type. The risk for personal injury varies with traffic environment type-traffic situation-means of conveyance (conflict class) and size of the conflict-arousing vehicle flows.

The risk quantity which is a measure of the probability that an accident with personal injuries would occur, can be estimated only on the basis of knowledge about the size of traveller-flows and risk for personal injuries in existing conflict classes.

The registration of travellers' behavior and serious conflict situations is executed through direct observation. The observations must be preceded by a training period for the observers and control studies must be executed before and during the observations in order to get a uniform interpretation of the definitions chosen. Registration of travellers' behavior is executed with an electronic gauge. The summing up is computer-based.

Results from an application of the method are presented in the report. These results sum up the safety effects of the traffic regulation performed in the center of the town of Uppsala, October 1, 1972, as well as they provide material for the first stage of the up-building of a general behavior data bank, which will constitute the basis for municipal programs against traffic accidents.

Through this method the planning can be based on a precise description of the risks and risk quantities of today, their probable change and precisely defined goals regarding traffic safety.

The summing up of the effectiveness of the regulation in Uppsala showed that traffic safety had been somewhat improved for all means of conveyance, an effect which in the first place is dependent on the measures taken in those routes

which got an increased traffic flow through the regulation.

The total reduction of risk quantity in the regulation in Uppsala was:

Pedestrians	5%
Cycles	2%
Cars	11%
All means of conveyance	5%

APPENDIX

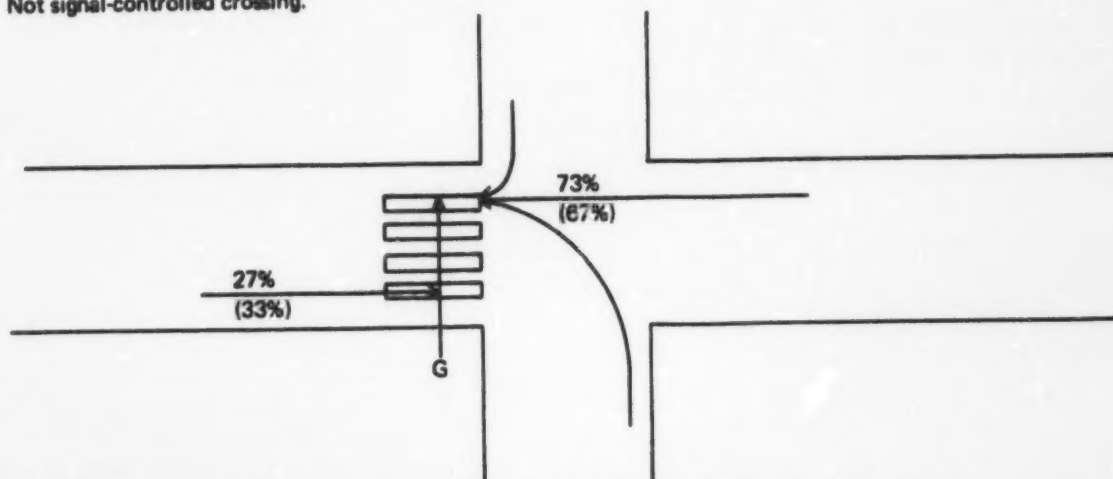
CALCULATION OF RELATION FIGURES FOR THE UPPSALA STUDY

	Ped.	Cycle	Car	Total
Personal injury accidents (PO)	21	56	34	111
PO/PO _{tot} (%)	18.9	50.5	30.6	
RM _{before} ^I RM = risk amount	1316	1515	1371	4202
RM _{fore} ^I /RM _{tot} ^I (%)	31.3	36.0	32.6	
Relation figure $r = \frac{PO/PO_{tot}}{RM_{fore}^I/RM_{tot}^I}$	0.60	1.40	0.94	

DISTRIBUTION OF ACCIDENTS AND RISK AMOUNTS ON CONFLICT-PRODUCING FLOWS OF VEHICLES

Pedestrian Traffic

Crossing of 2-lane street at marked zebra crossing.
Not signal-controlled crossing.



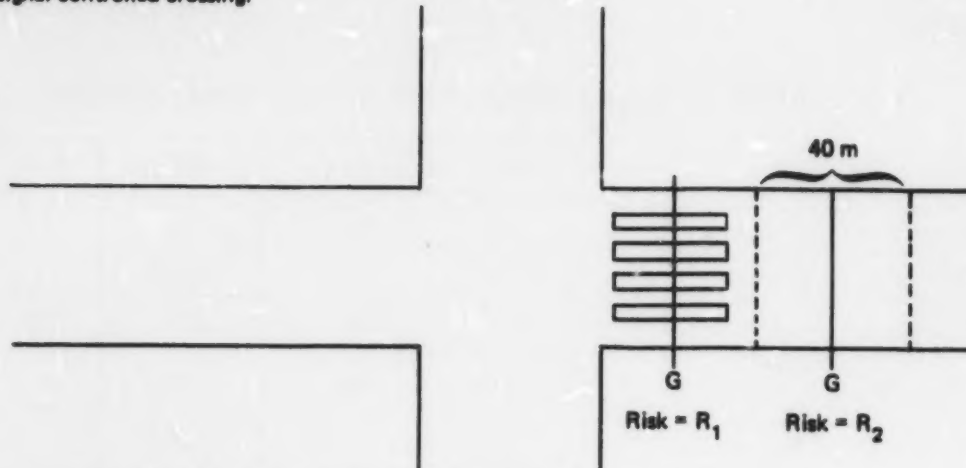
Figures without parenthesis: General distribution of accidents in the conflict class indicated.

Figures in parenthesis: General distribution of risk amounts taken from the behavior records in the conflict class indicated.

ACCIDENT RISK AND RISK ACCORDING TO THE BEHAVIOR DATA

Pedestrian Traffic

Crossing of 2-lane street on and near the marked zebra crossing.
Not signal-controlled crossing.



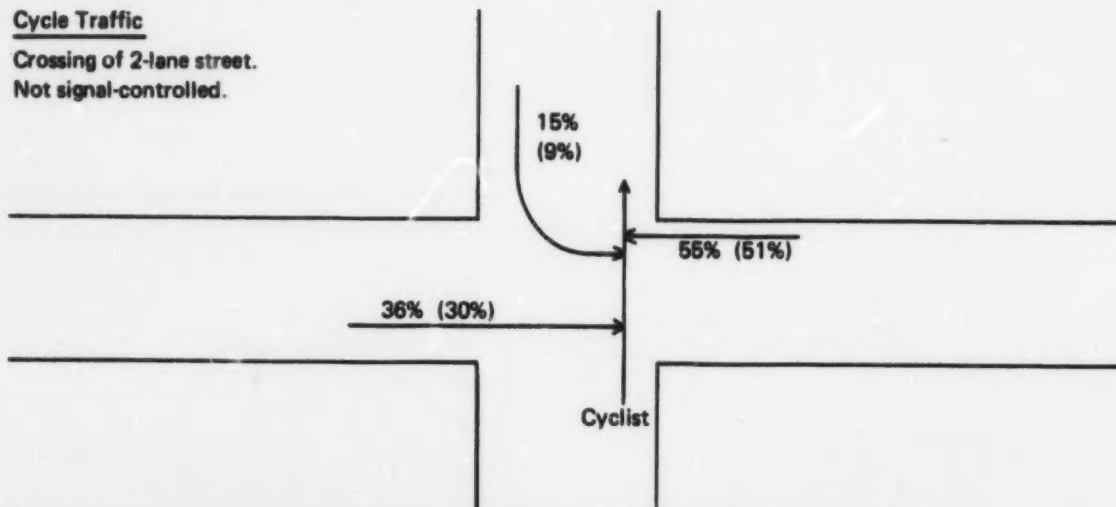
$\frac{R_2}{R_1}$: According to behavior study in the conflict classes indicated.

$\frac{R_2}{R_1}$: According to international research result based on analyses of accident data.

DISTRIBUTION OF ACCIDENTS AND RISK AMOUNTS ON CONFLICT-PRODUCING FLOWS OF VEHICLES

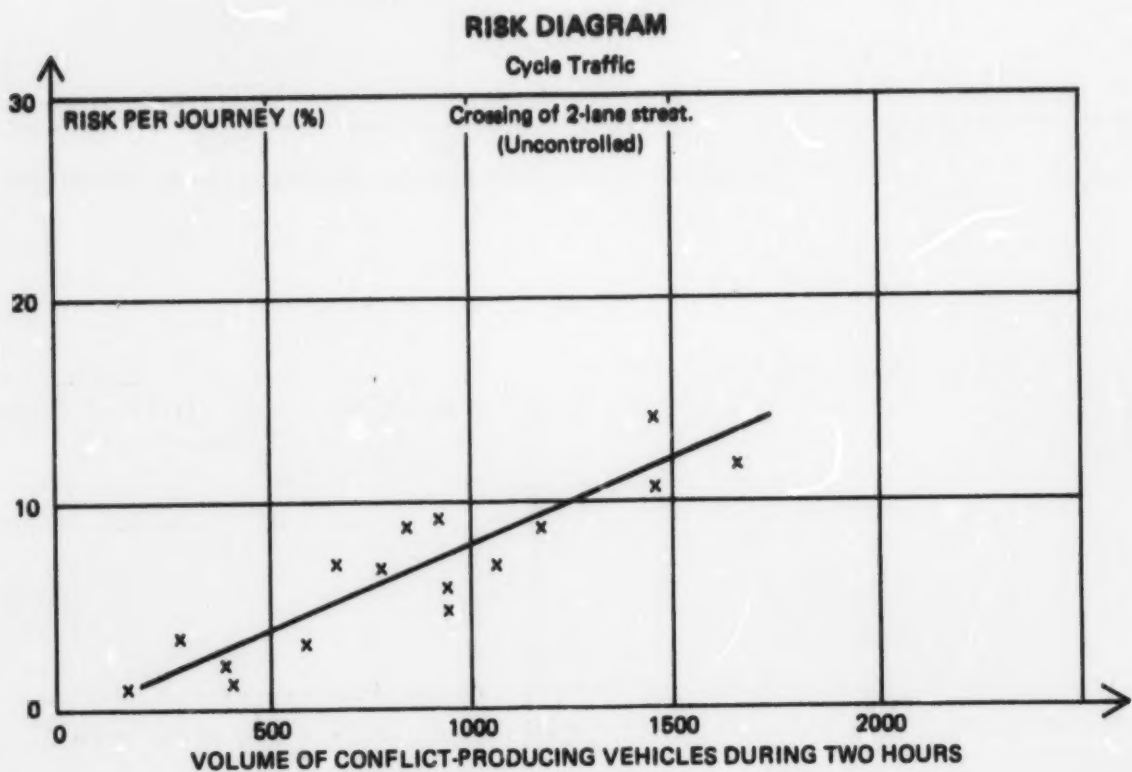
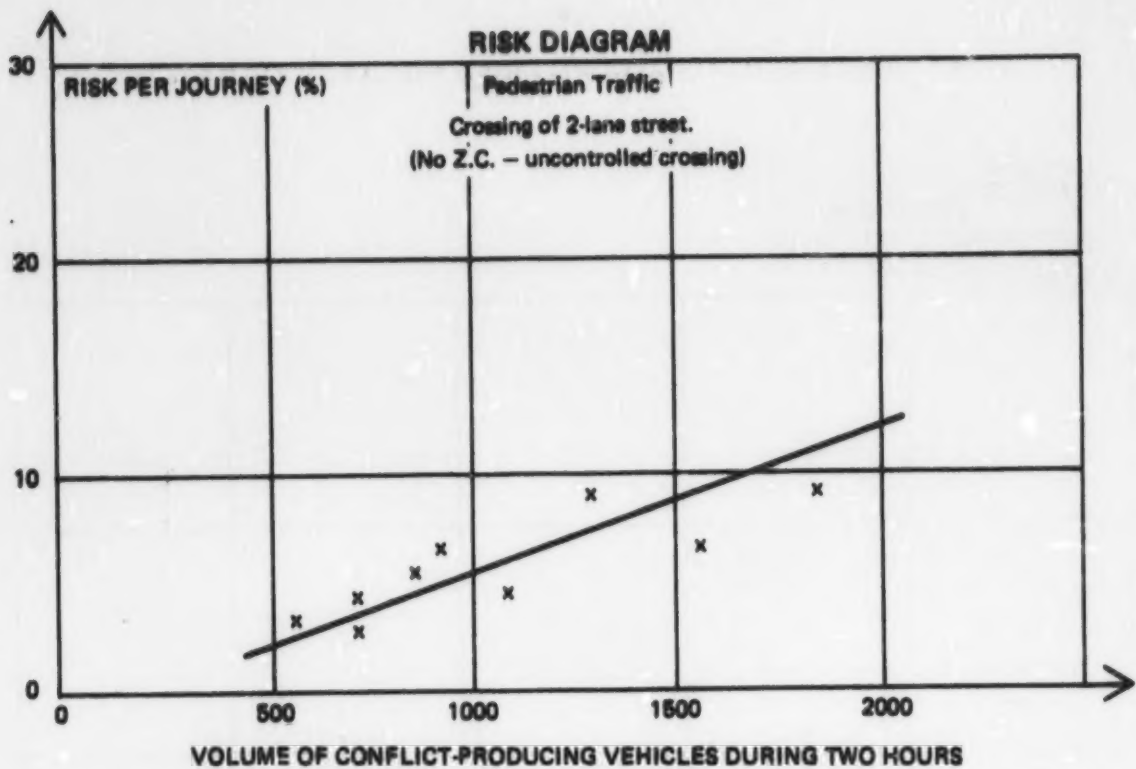
Cycle Traffic

Crossing of 2-lane street.
Not signal-controlled.



Figures without parenthesis: General distribution of accidents in the conflict class indicated.

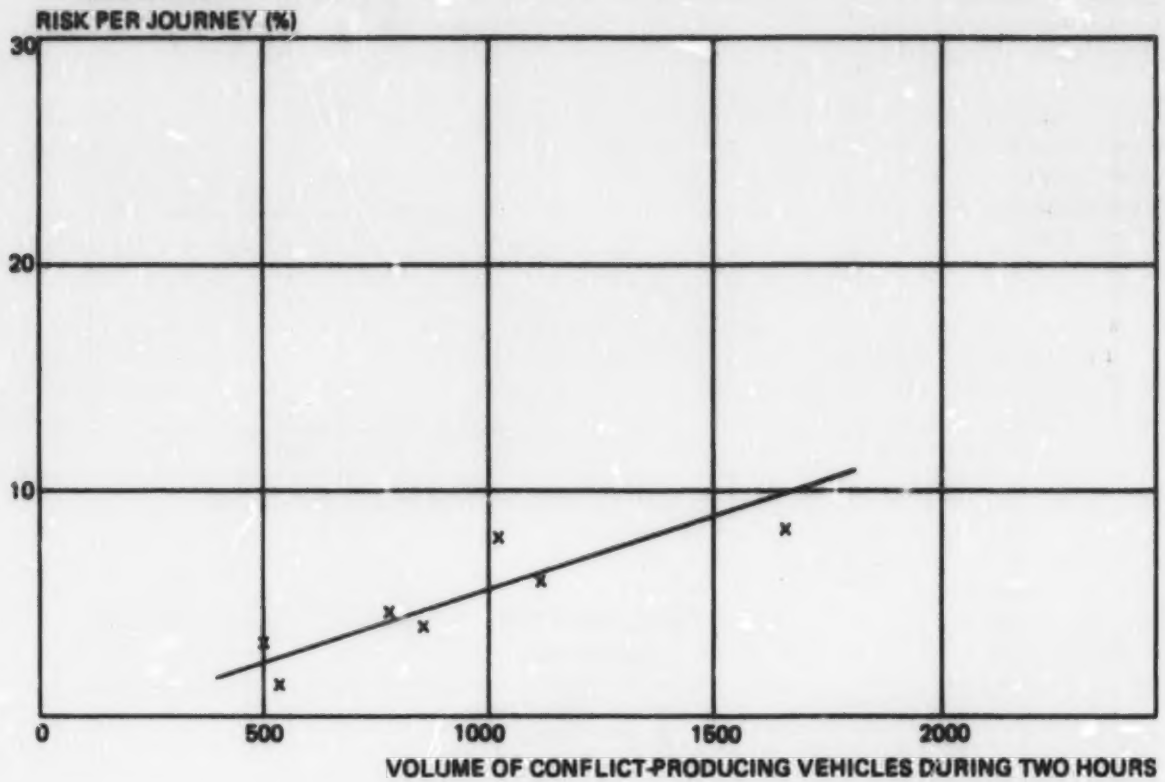
Figures in parenthesis: General distribution of risk amounts taken from the behavior records in the conflict class indicated.



RISK DIAGRAM

Car Traffic

Left turn in 2-lane crossing.
(Uncontrolled)



Recommendations On The Subject "Micro-Environment"

Dr.-Ing. Konrad Pfundt
*Leiter der Beratungsstelle Für
Schadenverhütung des HUK-Verbandes*

The following recommendations can be derived from the answers to the questions on this subject, other contributions by members of the group and from publications on the subject:

- Especially important is the protection of pedestrians wanting to cross the road.
- It does not suffice to protect those pedestrians wanting to cross roads with a high density of traffic. It is also important to provide safety for those pedestrians and playing children who want to cross roads with little traffic in residential areas and who will be inattentive because of the mostly low degree of traffic.
For the protection of these pedestrians, traffic lights, zebra-crossings, refuge islands and bridges or tunnels are of little use because pedestrians frequently cross roads with little traffic without regard for the traffic and accept detours only in rare cases. It is therefore recommended to lay down special speed limits to protect pedestrians in residential areas. Since, as a rule, the average distances travelled in residential roads are short, it should be acceptable to lay down a speed limit of e.g. 30 km/h in these areas. It is recommended not to indicate this speed limit for each road section by signs but to identify residential areas by special signs and to demand that the speed limit of e.g. 30 km/h must not be exceeded in this area.
- The best means of protecting pedestrians crossing the road are traffic lights. It is recommended to include pedestrian traffic, in principle, in the arrangement at existing traffic lights, at crossroads and at T-junctions, and to put up special signals for them. It has not been possible to prove that it will be of advantage to have these signals beaming in three colors — including yellow, too.
- Because of the high safety value of traffic lights and because of the special danger to pedestrians crossing the road at night, traffic lights should also operate at night, in principle.
- It has to be clarified how to switch the traffic lights set up exclusively for pedestrians. The views on this differ as follows:

- partly, traffic lights are permanently green for wheeled traffic, the signal for the pedestrians is permanently red but can be interrupted by pedestrians by pressing a button;
- partly, signals for vehicles and pedestrians are not on and the pedestrians can switch them on by pressing a button;
- partly, the signal for pedestrians is red but there is no green signal for vehicles (e.g. "Pelikan"). There are apparently many indications that the Pelikan system should be further developed.
- In many countries zebra-crossings are apparently not a suitable means of protecting pedestrians. The limits for the use of zebra-crossings are partly restricted locally and in terms of traffic to an extent that zebra-crossings can hardly be used. This is especially the case in those countries where motorists drive at rather high speed and without particular mutual consideration also in built up areas. However, as zebra-crossings have not proved particularly safe in countries with a high traffic discipline, it should be examined if zebra-crossings should not be given a different meaning (e.g. absolute priority for pedestrians even if they have not yet entered the zebra-crossing and with the obligation for motorists not to drive at speeds exceeding max. 30 km/h in these areas; zebra-crossings could possibly be used in connection with "transverse lines" which were used in Austria. However, these lines 15 m in front of crossings have apparently not proved themselves in Austria because of the lack of precise driving regulations.
- Any stopping and overtaking should be banned at a larger distance from zebra-crossings — as in England — and this ban should be indicated by markings in the roadway.
- Although the additional lights for zebra-crossings have evidently proved themselves (Germany, Denmark) it should be examined if the high lighting requirements have to be maintained or if it would not be better to abandon these requirements and to make zebra-crossings more conspicuous, e.g., by flash globules (as in England).
- In no case should zebra-crossings be used to mark crossings controlled by signals.

- The very differing stipulations concerning the necessary minimum distance between zebra-crossings and other points where pedestrian traffic is specially protected should be examined. The possibility must be created to set up protective devices also at smaller distances in roads with heavy crossing by pedestrians even if this

considerably interferes with wheeled traffic.

All these questions concerning the relative danger to pedestrians at points with differing protective devices and the creation of optimum protective devices should be thoroughly examined. The program developed by OECD does offer good leads for this purpose.

VEHICLE

Recommendations Submitted By The Pedestrian Safety Group

Injury To Pedestrians

Analysis Of The Behavior Of A Pedestrian In A Collision

Experiments On Behaviors Of A Pedestrian In A Collision With A Motor Vehicle

Experiments On Passenger Car And Pedestrian Dummy Collision

Pedestrian Safety Research

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**Recommendations Submitted By
The Pedestrian Safety Group**

The Pilot Project Group on Pedestrian Safety notes that on a worldwide basis the numbers of serious and fatal pedestrian casualties exceed those of any other category of road users.

The Group strongly recommends that the problem of pedestrian injury mitigation through improved vehicle design should accordingly be considered by Governments through biomechanics and vehicle structures research and development programs.

The Group further recommends that national ESV

specifications should include pedestrian protection. The Group suggests that in principle sound applicable injury tolerance criteria should be applied to the pedestrian in impacts up to 20 mph.

The Group further recommends that once developed and validated, vehicle design changes resulting from applied research programs and ESV programs should be incorporated in motor vehicle design requirements as soon as possible.

Injury To Pedestrians

G.M. Mackay,
University of Birmingham

ABSTRACT

This report reviews briefly what is known about the biomechanics of pedestrian collisions. Some epidemiological considerations are mentioned and then pedestrian injuries and their origins are discussed. The influence that vehicle shape and resilience have on pedestrian injury is thought to be considerable and bumpers of cars are singled out as one particular feature which should be improved immediately. The relative influence of vehicle and road surface contacts are discussed and means of mitigating the latter are mentioned briefly. The high pedestrian involvement with taxis and public service vehicles is suggested as one area where vehicle design changes might be initiated.

Recommendations for further research in the area of pedestrian injury mitigation are given, together with other aspects of vehicle design which have some effect on pedestrian accident involvement such as vehicle lighting and the introduction of non-lock braking.

ACKNOWLEDGEMENTS

This report has been prepared by Dr. G.M. Mackay for the CCMS Committee on Pedestrian Safety and has been approved by that Committee. It is submitted in support of the recommendation of the Committee to the CCMS-NATO Council.

This report has been made possible through the financial support of the Science Research Council, which has provided funds for accident research at the Department of Transportation and Environmental Planning, University of Birmingham (U.K.). Part of this work has been directed at the pedestrian accident problem.

INTRODUCTION

This report discusses briefly the state of knowledge of pedestrian injury in relation to vehicle design. It has been written to be short deliberately and, therefore, it is selective in the subjects discussed and in the references quoted. A comprehensive

bibliography has been compiled, however, so that further detailed study may be made by those who wish to do so.

The aim of the report is to illustrate the circumstances of pedestrian trauma, its extent, origins and means of mitigation. Recommendations for action and for further research are given at the end.

EPIDEMIOLOGY

Although small in comparison to the literature on vehicle occupant injury, there is a surprisingly large number of sources of information on pedestrian injuries (see bibliography). As far as general epidemiological considerations are concerned, it would appear likely that on a worldwide basis, if road users are classified conventionally into car occupants, motorcyclists, bicyclists, occupants of heavy goods vehicles, occupants of public service vehicles, and pedestrians, then in terms of traffic fatalities, pedestrians are the largest single group. Proportions vary greatly from the United States where 10% of fatalities are pedestrians (77% vehicle occupants, 5% riders), through Great Britain where 41% are pedestrians (40% vehicle occupants, 19% riders) to Poland where 46% are pedestrians (38% riders, 8% car occupants and 8% occupants of other vehicles, mainly buses). No firm data are available from countries where the car is present in only relatively small numbers, but in those very countries pedestrians predominate as the main victims of traffic accidents (36).*

In passing, it should be noted that we conventionally limit our definition of pedestrian accidents to impacts between road vehicles and pedestrians which result in an undesirable energy exchange between the vehicle and/or the road surface and the pedestrian. Such a definition does not describe the total environment of pedestrian injury to the satisfaction of an academic epidemiologist. Merely to stimulate thought, it should be recalled that a large number of pedestrians are injured in falls or contacts with the road environment, no road vehicle being involved. Such occurrences should be

*(Numbers in parentheses refer to references listed at the end of this report.)

considered to be within the province of the traffic engineer who designs curbs, steps, ramps, footpath surfaces, road furniture and all the other features which influence these "single-vehicle" pedestrian-only accidents.

Only those epidemiological characteristics of pedestrian accidents relevant to the biomechanics of the problem will be considered in this report. Pedestrians who are injured are mainly the young; in the U.K., one third of serious pedestrian casualties are under 10 years of age. There is a preponderance of males over females, although not nearly as marked as for car occupants. The elderly can also be identified as a high involvement group, particularly when fatalities only are considered. Presumably the fact that the elderly are less able to recover from serious trauma is of some importance here. With the elderly, as with the young, males predominate over females in a ratio of some three to one (for fatalities over 65 years of age).

Some studies have also isolated a third high risk group among pedestrians, the intoxicated middle-aged male. The American experience (8) suggests that alcohol is an important factor in pedestrian accidents, and although the parallels between Europe and North America are not necessarily close, it would seem to be an important subject for further research.

Another useful area of study would be to identify those vehicles which are used in environments where the risk of collision with a pedestrian is high. Work by Smeed (34) shows that the involvement rate with pedestrians for public-service vehicles in Britain is some six times that of cars when compared on the basis of accidents per year per 1000 vehicles licensed. Similarly the rate for goods vehicles is almost twice the car rate. Such comparisons where pedestrian accidents per year per 1000 vehicles licensed give the risk to each type of vehicle. This is the appropriate measure when one is considering the involvement of the various classes of vehicles relative to each other in design terms, and vehicle mileage is not relevant here. Indeed, if one assumes that public service vehicles have a lifespan twice that of the average car, then per vehicle the chance of pedestrian involvement is twelve times that of a car, i.e. over the working life of a bus, it is twelve times more likely to injure a pedestrian than a passenger car.

Other particularly high risk situations have been uncovered. For example, taxis in New York City have a very high pedestrian accident involvement rate. McLean (24) has shown that in two years in Manhattan the average taxi has a one in eight chance

of injuring a pedestrian. It is reasonable to suggest that taxis in other large cities (Tokyo, London, Paris or Brussels) may have similar involvement rates.

Pedestrian injury is known to be largely an urban problem, (in Britain for example 90% of all serious pedestrian casualties occur in urban areas (18)) and so the impact speed question is perhaps not as severe as might be thought. This will be discussed further below.

INJURIES

Pedestrians predominantly receive injuries to the lower limbs and to the head (10, 11, 16, 27). On average, a seriously injured pedestrian receives at least 2.5 injuries to different regions of the body per person (19). On the whole children receive less severe injuries per accident than adults (20). This appears to be because the impact circumstances of child pedestrian accidents are somewhat more favorable in that speeds are lower than for adults, although doubtless other considerations also apply. The elderly pedestrian, once involved in an accident, is much more likely to die than a younger person (9, 39). This is in part due to the greater likelihood of a given injury being fatal in an elderly person.

In considering design aspects of vehicle exteriors, therefore, there are two general anatomical considerations. Over one third of all people struck by vehicles will be small, less than approximately four feet six inches tall. Also any injury tolerance values used are likely to vary by factors up to five for the range of the population who are exposed to the impacts.

SOURCES OF INJURY

Two sorts of research have been conducted in attempts to evaluate how pedestrians receive their injuries. These are field studies of real accidents on the one hand and laboratory studies with dummies or with computer simulation on the other.

Detailed field studies have been conducted in Australia (29), the United States (3, 10) and in Britain (20, 21). These projects have illustrated the configurations of pedestrian accidents, estimated speeds involved and outlined the frequencies with which various parts of the car cause injury.

At least 70% of all pedestrians are struck by the front of vehicles, and this figure rises to over 90% when only fatal and serious injuries are considered. The nearside front corner is struck with a frequency 50% greater than the offside (driver's) front corner.

The sides of cars strike pedestrians in some 30% of cases, decreasing to less than 10% for serious and fatal categories. These side impact accidents mainly involve children running into the sides of relatively slowly moving vehicles. Five times as many of these side collisions occur on the nearside than on the offside, i.e., most pedestrians are struck as soon as they enter the roadway rather than when they are over half way across.

Very few pedestrians are struck subsequently by a second vehicle. This has been raised as a possible objection to design modifications which would deflect the pedestrian into the path of an oncoming car (14). This would appear not to be an important consideration because most pedestrians are struck by the nearside half of the car.

The incidence of pedestrians being run over is remarkably low (estimated at less than 2%). This is because in most configurations the center of gravity of the pedestrian is above the first point of contact on the vehicle so that the pedestrian is rotated onto the front, typically receiving blows to the lower leg, thigh, hip, thorax and head in that order. Often the head contact is with the windscreen or windscreen frame (18).

The pedestrian is then accelerated up to the speed of the striking car. If the car is now braked suddenly, then the pedestrian is projected from the car to receive a second series of impacts from the road surface. Alternatively, at higher speeds, the pedestrian may go over the car completely by cartwheeling over the roof to land on the road surface behind the car.

Even in cases where the center of gravity of the pedestrian is lower than the front of the car, it appears from field studies that braking of the striking vehicle is initiated before, at or very shortly after impact. Thus the pedestrian is accelerated sharply up to the speed of the vehicle which is then braked suddenly. The pedestrian is projected forwards and downwards, but even when sliding or rolling on the road surface he requires a greater distance in which to stop than most vehicles which are braking under emergency conditions.

These findings have also been shown experimentally using dummies (32, 38).

The relative frequency of injuries from the primary contacts with the vehicle have been compared with the injuries received in secondary contacts with the road surface (17). Although the road surface generates many minor injuries, at least 60% of severe and fatal injuries come from the primary contacts with the car.

The field studies have given estimates of the vehicle speeds involved in pedestrian collisions. There is good agreement between these studies (8, 9, 21, 29) even though one was conducted in Adelaide, Australia, one in New South Wales, one in the United States and one in Birmingham, England. The mean speed appears to be some 20 mph with speeds going down to zero (for the vehicle) and up to 50 mph, but with over 85% occurring at less than 30 mph.

Specific vehicle components (such as emblems and insignia) have not been identified as the sources of frequent injury with the exception of nearside wing mirrors (20). On the other hand, general parts of the car have been named in many of the studies. Bumpers in particular are the outstanding source of injury, followed in frequency by wings and headlights (17).

Laboratory studies with dummies and computer simulations show in detail the form of pedestrian kinematics described above. Such studies cannot, however, answer questions to do with the frequency of particular events. A most useful computer simulation (3) has examined the effects of changes in vehicle shape and resilience on the trajectories of both adult and child pedestrians. This work has shown that both contour and stiffness influence the injury circumstances.

VEHICLE DESIGN — THE COLLISION PHASE

The work quoted above has outlined briefly some of the circumstances of pedestrian injury. A recent study has confirmed a likely conclusion that exterior vehicle design does in fact influence pedestrian injuries.

McLean (25) has examined a large sample of pedestrian accidents and shown, by comparing pedestrians hit by Volkswagens with pedestrians hit by Cadillacs, that vehicle factors do in fact influence the severity of injury. Factors such as speed, pedestrian age and environmental differences were allowed for. This study concludes that if all cars had Volkswagen fronts, then 30% of all pedestrian fatalities in the United States would be saved.

In general, therefore, it would appear that a large number of pedestrians are hit at relatively low speeds (below 25 mph), that the majority of their serious injuries come from vehicle contacts, and that vehicle design does in reality influence the pattern and severity of their injuries.

Bumpers stand out as the one single part of the vehicle most susceptible to improvements. Present bumper heights are at just the wrong level in that the maximum bending moments are being applied across

the knee joint. Fractures with no joint involvement are preferable in that the clinical prognosis is much better. Simple facing of bumpers with a suitable load spreading material would be beneficial (30). A general lowering of bumper heights would also appear to be desirable, together with as much yielding of the bumper structure below the load levels which cause fracture as possible. Similarly wing and bonnet structures should be contoured to have greater resilience with the removal of hard spots which cause damage at the thigh and pelvis level, or in the case of children at abdominal level.

The prevention of head injury during impact with the vehicle presents a more intractable problem. Much head trauma appears to come from contacts with the windscreen and its frame, and it would seem that shape rather than resilience is the factor most amenable to modification. Cars with bonnets long enough to avoid these direct head impacts with the windscreen would seem to offer a lower risk of high-energy blows to the head, while high rake angles on windscreens may well be beneficial in this respect as well. This is a subject which should be examined by computer simulation techniques.

Looking at the car in plan view, it has been suggested that a rounded "bow" would benefit pedestrians. Such a shape would deflect the pedestrian away from the car (mainly on the nearside) and would produce several low energy impacts rather than a few blows of high energy. Such a design would also tend to spin the pedestrian, and the effects of such a rotation are not known, and might well be serious.

It has been suggested by several authors that because of the problem of secondary impacts with the ground, it is important to retain the pedestrian on the vehicle as the latter comes to rest (12, 14, 38). Work in Japan is currently underway examining this possibility. So far the designs which would perform this function represent radical departures from existing practice, but it obviously represents an area where research is greatly needed. The use of new materials which have high yield and high friction properties would also appear to be an area worthy of study.

VEHICLE DESIGN - BEFORE IMPACT

There are other features of vehicle design which influence pedestrian accidents which should be mentioned. Approximately half of all serious pedestrian casualties occur at night (although this proportion varies from country to country

considerably). Vehicle lighting is a parameter of consequence therefore, and it can be suggested that pedestrians are particularly vulnerable in a mixed lighting environment where some cars use dipped headlights while others use "parking" lights. The typical pedestrian accident involves a pedestrian stepping into the path of an approaching car, having not registered the latter's presence. Because pedestrian injury is a much greater problem in urban areas than car occupant injury, it is suggested that vehicle lighting, and indeed environmental lighting, should be considered primarily from the point of view of the pedestrian. In particular, uniformity in the use of vehicle lights would appear to be desirable.

Car color is also a parameter which is likely to be of some consequence to pedestrian accidents. There is no data available to suggest what influence color may have but it is perhaps a topic worth examining.

Non-lock braking is likely to be introduced at some time in the future, now that the technology is well developed. The maintenance of directional control and "swervability" under emergency braking is likely to be of some benefit in the pedestrian situation. It would be useful to examine a sample of pedestrian accidents to assess the likely proportion of such accidents which might be avoided with the introduction of direction control under hard braking.

RECOMMENDATIONS

In Europe, Australia, Japan and indeed all the motorized world, with the exception of North America, pedestrians (as serious and fatal casualties) equal or outnumber passenger car occupant casualties. Almost all such pedestrian casualties are struck by the front of cars. By contrast, car occupant casualties represent a range of crash configurations in which only some 55% involve the front structure of the car, the remainder being side or rear impacts or rollover (19). Therefore, it is logical to suggest that at least half of the front structure of a car should be considered mainly as a structure with which to hit a pedestrian, rather than a structure to decelerate the car occupants.

The high incidence of lower limb injuries from bumpers is well established in the literature. It is recommended therefore that an immediate action program be initiated to improve the position, shape, resilience and load spreading characteristics of bumpers. This appears to be the one design aspect of cars which generates considerable morbidity, and is separately identifiable from the rest of the car structure. Improvements from the pedestrian point of

view to the bumpers are not necessarily incompatible with protection against property damage.

Apart from bumper design, this short review suggests the need for a greatly increased research effort. The state of knowledge indicates that the crash phase of pedestrian collision is amenable to treatment and that a variety of subjects should be explored. In particular the following research areas are suggested:

- Prospective detailed field studies of representative samples of pedestrian collisions aimed at identifying the specific vehicle structures which cause injury, examining the field performance of the common models of car, and describing in greater detail collision speeds, the role of impacts with the road and other factors.
- Retrospective studies of large numbers of pedestrian accidents (using city, regional or national records), combined possibly with questionnaire surveys, to examine pedestrian injury severity by make and model, corrected for whatever exposure differences can be evaluated.
- Identification of specific high risk vehicles, for example taxis and buses which are used in areas with high pedestrian accident involvement rates. Changes in the design of such vehicles are likely to have greater cost/benefit justification than across the board modifications.
- The development of computer simulation procedures to evaluate a much greater range of vehicle shapes and resilience characteristics than has so far been attempted. Such a project should give guidance as to the optimum characteristics which the front structure of vehicles should have.
- Experimentation with human subjects and cadavers to attempt validation of computer simulation of contact forces, body-vehicle interaction and kinematics.

As well as these research projects on the biomechanics of pedestrian injury, there are other subsidiary aspects of pedestrian accidents which have been mentioned above and which appear to be worthy of further study. These are:

- An evaluation of the role of alcohol in adult pedestrian accidents.
- A study of the costs of pedestrian accidents and various cost/benefit strategies aimed at reducing accidents and injuries.
- A study of the likely effect of the introduction of non-lock braking on pedestrian accidents.

REFERENCES

1. Bienl, B.M., Older, S.J. and Griep, D.J. *Pedestrian Safety*. A report by an OECD Road Research Group. October 1969.
2. Bull, J.P., *International Comparisons of Road Accident Statistics*. Journal of the Institute of Highway Engineers, Vol. 15 No. 3. March 1968, pp. 15-19.
3. Cornell Aeronautical Laboratory, Inc. *Research in Impact Protection for Pedestrian and Cyclists*. CAL Technical Report No. VJ-2672-V-2. May 1971.
4. Ekström, G., Gastrin, U. and Qvist, O. *Traffic Accidents Among Children*. From: Proceedings of the Second Congress of the International Association for Accident and Traffic Medicine. Stockholm. August 1966.
5. Fisher, A.J. and Hall, R.R. *The Relationship between Injuries to Pedestrians and Frontal Design of Motor Vehicles Involved in Collision with Pedestrians*. Part 2: *Results and Discussion*. Research Project RP 212, Department of Motor Transport, New South Wales, Australia. August 1970.
6. Gädeke, R. *The Road Accident Risks in Children and Youth. The Morbidity Pattern*. From: Proceedings of the Second Congress of the International Association for Accident and Traffic Medicine. Stockholm. August 1966.
7. Gögler, E. *Road Accidents*. Series Chirurgica, Documentat Geigy. Manchester, 1965.
8. Haddon, W. Jnr., Vallen, P., McCarroll, J.R. and Umberger, C.J. *A controlled Investigation of the Characteristics of Adult Pedestrians Fatally Injured by Motor Vehicles in Manhattan*. Journal of Chronic Diseases, 14:6 655-678. December 1961, and Traffic Safety Research Review, 7:2 5-18. June 1963.
9. Hall, R.R. and Fisher, A.J. *Some Factors affecting the Trauma of Pedestrians Involved in Road Accidents*. Paper to the 43rd Anzaas Congress, Brisbane. May 1971.
10. Huelke, D.F. and Davis, R.A. *Pedestrian Fatalities in Wayne County, Michigan*. Highway Safety Research Institute Report No. Bio-9. University of Michigan. 1969.
11. Jamieson, K.G. and Tait, I.A. *Report of a General Survey: Traffic Injury in Brisbane*. National Health and Medical Research Council Special Report Series No. 13. Canberra. 1966.
12. Japan Automobile Manufacturers' Association, Inc. *Experiments on Behaviours of a Pedestrian*

- in Collision with a Motor Vehicle*. CCMS Summarized Report No. 33. August, 1968.
13. Katayama, K. and Shimada, T. *Analysis of the Behavior of Pedestrians in Collision - Mathematical Analysis*. CCMS Report No. 34. Safety Lab. Isuzu Motors Ltd.
 14. Kondo, M. and Taneda, K. *Some Results of Vehicle-Pedestrian (Dummy) Collision Tests made recently in Jari*. (Preliminary Report). Paper presented at the Meeting of Experts on Pedestrian Safety, September, 1971, Brussels. Sponsored by Fonds d'Etudes pour la Sécurité Routière.
 15. Mackay, G.M. *Automobile Design and Pedestrian Safety*. International Road Safety and Traffic Review, XIII, 3, pp. 29-32. 1965.
 16. Mackay, G.M. and Ponseka, C.P. *Aspects of Urban Traffic Injury*. From: Proceedings of the 11th Stapp Conference, Anaheim, California. SAE Report No. 670910, pp. 70-78. October 1967.
 17. Mackay, G.M. *Traffic Injury in Urban Environments*. From: Proceedings of International Conference on Biomechanics, Fonds d'Etudes pour la Sécurité Routière, Brussels, Vol. 1 pp. A2.1-A2.25. September 1968.
 18. Mackay, G.M. *The Other Road Users*. 13th Annual Conference of the American Association for Automotive Medicine. University of Minnesota, October 1969.
 19. Mackay, G.M. *Aspects of Emergency Care - Some Features of Traffic Accidents*. British Medical Journal. Vol. 4 No. 5686. pp. 799-801. December 27th, 1969.
 20. Mackay, G.M. and McLean A.J. *The Exterior Collision*. XIIIth FISITA Congress and 1970 International Automobile Safety Conference. May/June 1970. Published by FISITA and SAE, Paper No. 23 2/12. pp. 1214-1221.
 21. Mackay, G.M. *Pedestrian, Cyclist and Motorcyclist Accidents*. Forensic Science Society, Spring Symposium, Warwick. 1971. (in press)
 22. McLean, A.J. *The Man in the Street - Pedestrian Accidents in the Empire State*. Published in the Proceedings of the 15th Annual Conference of the American Association for Automotive Medicine by the Society of Automotive Engineers. New York, 1972.
 23. McLean, A.J. *The Other Road Users: The Pedestrian, Cyclist and Motorcyclist*. Proceedings of the 3rd IAATM Triennial Congress on Medical and Related Aspects of Motor Vehicle Accidents. May/June 1969. pp. 85-88.
 24. McLean, A.J. *The Epidemiology of Pedestrian Highway Injury. Chapter III. Car Make and Pedestrian Injury*. Thesis for Sc.D., Harvard University. School of Public Health. January 1972.
 25. McLean, A.J. *Car Shape and Pedestrian Injury*. From: Proceedings of Symposium on Road Safety. Expert Group of Department of Shipping and Transport. Canberra, Commonwealth of Australia. March 1972.
 26. Norman, L.G. *Road Traffic Accidents - Epidemiology, Control and Prevention*. World Health Organization, Geneva, 1962. Public Health Paper No. 12.
 27. Robertson, J.S., McLean, A.J. and Ryan, G.A. *Traffic Accidents in Adelaide, South Australia*. Australian Road Research Board Special Report No. 1. July 1966.
 28. Rodstein, M. *Pathological and Physiological Changes in Older Adults: Effects on Drivers and Pedestrians*. From: Proceedings of the Third IAATM Triennial Congress on Medical and Related Aspects of Motor Vehicle Accidents. May/June 1969. pp. 55-61.
 29. Ryan, G.A. and McLean, A.J. *Pedestrian Survival*. Adelaide University (Australia). From: Proceedings of the 9th Stapp Car Crash Conference. Published by University of Minnesota, General Extension Division (1966). pp. 321-334.
 30. Samal'he, S. and Hearn, B.M. *Deformation Characteristics of Cars in Tests to Simulate Pedestrian Impact*. Structures and Materials Technical Memorandum 196. Aeronautical Research Laboratories, Australian Defense Scientific Service. Melbourne 1971.
 31. Severy, D.M. and Brink, H. *Auto-Pedestrian Collision Experiments*. SAE - 660080. Automotive Engineering Congress, Detroit, Michigan. January, 1966.
 32. Severy, D.M. *Auto-Pedestrian Impact Experiments*. University of California, Los Angeles. From: Proceedings of 7th Stapp Car Crash Conference. Published by Charles C. Thomas (1966) p. 345.
 33. Shaw, A. and Rezwi, A. *Child Pedestrian Accidents in Central Harlem 1968*. The Journal of Trauma, Volume 11, No. 4, 1971.

34. Smeed, R.J. *Aspects of Pedestrian Safety*. Journal of Transport Economics and Policy. Volume 1, No. 3, September 1968. Paper given to the International Federation of Pedestrians, April 1968.
35. Solheim, K. *Pedestrian Deaths in Oslo Traffic Accidents*. British Medical Journal 1, January 1964. pp. 81-83.
36. United Nations. *Statistics of Road Traffic Accidents in Europe 1966*. Economic Commission for Europe. New York, 1968. E/ECE/710. E/ECE/TRANS/555. Sales No. 68/11/E/Mlm. 18
37. Wakeland, H.H. *Systematic Automobile Design for Pedestrian Injury Prevention*. From: Proceedings of the 5th Stapp Automotive Crash and Field Demonstration Conference. Published by the University of Minnesota, Center for Continuation Study. 1962. pp. 193-218.
38. Watanabe, A. *Review on the Pedestrian Safety Research in Japan*. Technical Presentation for Experimental Safety Vehicles Conference. Paris. January, 1971.
39. Wiener, E.L. *The Elderly Pedestrian: Traffic Safety's Mystery Man*. From: Proceedings of the Third IAATM Triennial Congress on Medical and Related Aspects of Motor Vehicle Accidents. May/June 1969. pp. 52/56.

Analysis Of The Behavior Of A Pedestrian In A Collision

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We tried to numerically analyze motions of a pedestrian with seven degrees of freedom, by modeling vehicle-to-man collision.

According to comparison of the numerical computation with experimental data, they offer nearly good results. Thus, it was assured that modeling was a reasonable attempt and could make use of these simulations of the analysis of phenomena in vehicle-to-man collision.

INTRODUCTION

When a car strikes a pedestrian, the latter is always found to be a victim. In addition, such an accident often results in the death or serious injury of the pedestrian involved, making itself a grave social concern.

Improvement of road and traffic conditions, enhancement of traffic morale and improvement of vehicle itself will be necessary measures to cope with the occurrence of such accidents. As far as the improvement of automobiles is concerned, some measures have already been taken, covering the elimination of protrusion around door knob, fender mirror, etc. and attachment of side guard to heavy truck.

Regarding the man-to-vehicle collision, a number of experiments have been put under way not only by manufacturers but also by universities as well as other specialized institutions, to promote fundamental study of the safety measures of pedestrians.

There are, however, many factors that affect the behavior of a pedestrian at the time of collision with a vehicle, and it is extremely difficult to analyze the behavior of a pedestrian or to estimate the degree of impact and damage on the victim from collision experiment results, employing anthropomorphic dummies and cars. In addition, a huge amount of experiment will be damage on the victim from collision experiment results, employing anthropomorphic dummies and cars. In addition, a huge amount of experiment will be required to obtain

accurate data under such situation. Thus, an attempt has been made herein to numerically analyze the motion of a pedestrian with seven degrees of freedom, by modeling man-to-vehicle collision for simplicity.

MODELING OF PEDESTRIAN-TO-VEHICLE COLLISION

Equation Of Motion Of Pedestrian

Dynamic model of a pedestrian is based on the same concept as the behavior analysis of an occupant of a car at the time of collision, and as shown in Figure 1(a) it consists of five rigid units — head,

DYNAMIC MODEL OF A PEDESTRIAN

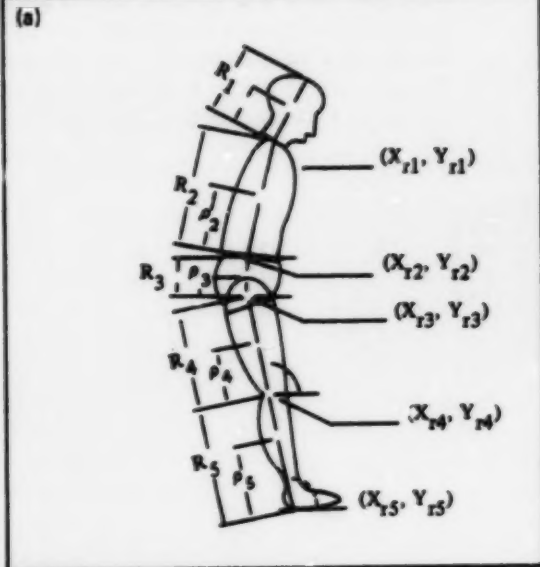


FIGURE 1

waist, hip, thigh and leg, each unit being connected by pin joints to give seven degrees of freedom.

As shown in Figure 1(b) if a pair of compression load F_k and friction force F_{rk} from the vehicle and vertical load F_t and friction force F_{rt} from the road surface act on each of the five rigid units, and also if gravity is taken into account, the equation of motion of a pedestrian will be as follows:

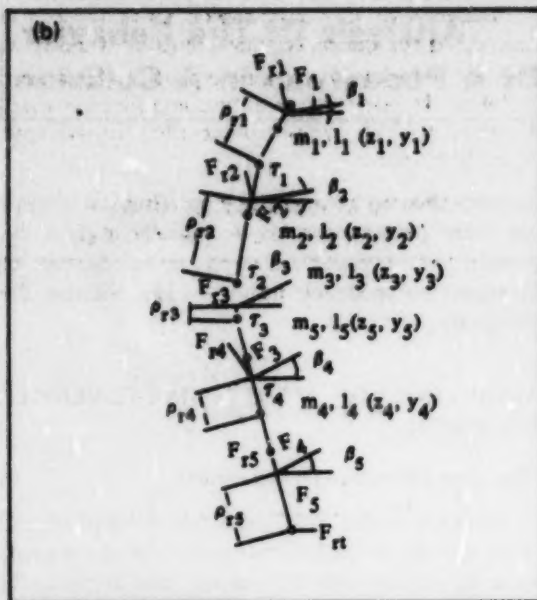


FIGURE 1 (Continued)

NOTE: External force does not always act on each rigid unit. So in that case, F_k and F_{rk} are to be considered zero. It is probable that two forces act simultaneously on one rigid unit. In that case, the extra force can be added. (see appendix regarding matrix (A) - (G)).

$$A \begin{bmatrix} \theta_1 \\ \theta_2 \\ \theta_3 \\ \theta_4 \\ \theta_5 \\ z_1 \\ y_2 \end{bmatrix} = (B) \begin{bmatrix} \theta_{12}^2 \\ \theta_{22}^2 \\ \theta_{32}^2 \\ \theta_{42}^2 \end{bmatrix} + (C) \begin{bmatrix} \tau_1 \\ \tau_2 \\ \tau_3 \\ \tau_4 \end{bmatrix} + (D) \begin{bmatrix} F_1 \\ F_2 \\ F_3 \\ F_4 \\ F_5 \end{bmatrix} \\ + (E) \begin{bmatrix} F_{r1} \\ F_{r2} \\ F_{r3} \\ F_{r4} \\ F_{r5} \end{bmatrix} + (F) \begin{bmatrix} F_t \\ F_{rt} \end{bmatrix} + (G)$$

Characteristics Of Human Body Joints

Regarding the characteristics of the pin-joints, the characteristics relative to relative angular displacement and velocity were considered.

SPRING CHARACTERISTICS OF JOINTS

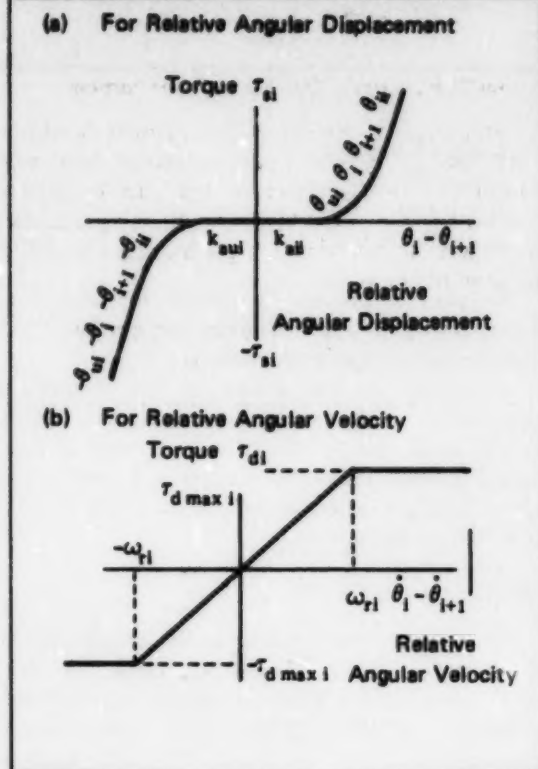


FIGURE 2

- Characteristics of relative angular displacement. ($i = 1-4$).

- $\theta_{u1} > \theta_i - \theta_{i+1} > \theta_{l1}$
 $\tau_{si} = 0$
- $\theta_i - \theta_{i+1} > \theta_{u1}$
 $\tau_{si} = k_{suf}(\theta_i - \theta_{i+1} - \theta_{u1})^2$
- $\theta_i - \theta_{i+1} < \theta_{l1}$
 $\tau_{si} = -k_{sil}(\theta_i - \theta_{i+1} - \theta_{l1})^2$

- Characteristics of relative angular velocity.

- $\omega_i > \dot{\theta}_i - \dot{\theta}_{i+1} > -\omega_i$
 $\tau_{di} = \frac{\tau_{d \max i}}{\omega_i} (\dot{\theta}_i - \dot{\theta}_{i+1})$
- $\dot{\theta}_i - \dot{\theta}_{i+1} > \omega_i$
 $\tau_{di} = \tau_{d \max i}$

$$(c) \quad \dot{\theta}_1 - \dot{\theta}_{i+1} > -\omega_1$$

$$\tau_{d1} = -\tau_{d \max i}$$

Spring Characteristics Of Vehicle Front Portion

With regard to the spring characteristics of vehicle front portion, studies were separated into two categories – one involving the highly rigid cornered portion including front bumper or hood tip, and the other generally not very rigid panel portion including radiator grill or hood.

MODELING OF A FRONT PORTION OF THE VEHICLE

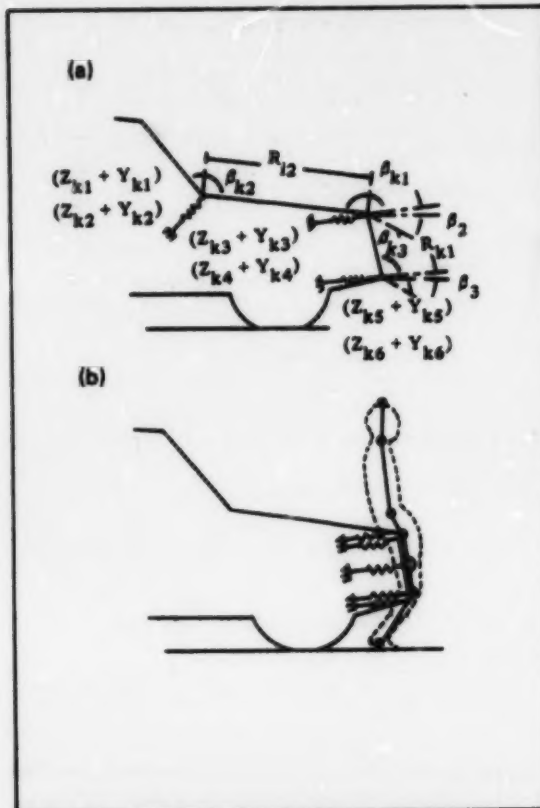


FIGURE 3

As far as the load on the cornered portion is concerned, the acting point was not limited and it was supposed that the force acts through an arbitrary point on the pedestrian, where the cornered portion of the vehicle gets into contact. For the panel portion, the acting point was limited for simplification, and the force was supposed to act through the gravity center of the rigid unit involved, pin joints, head top and heel.

Incidentally, only compression deformation was considered for the spring characteristics as shown in Figure 4, taking into account the plastic deformation.

When the body deforms, bottoming or buckling, choice is available arbitrarily according to the input of characteristics.

SPRING CHARACTERISTICS OF A FRONT PORTION OF THE VEHICLE

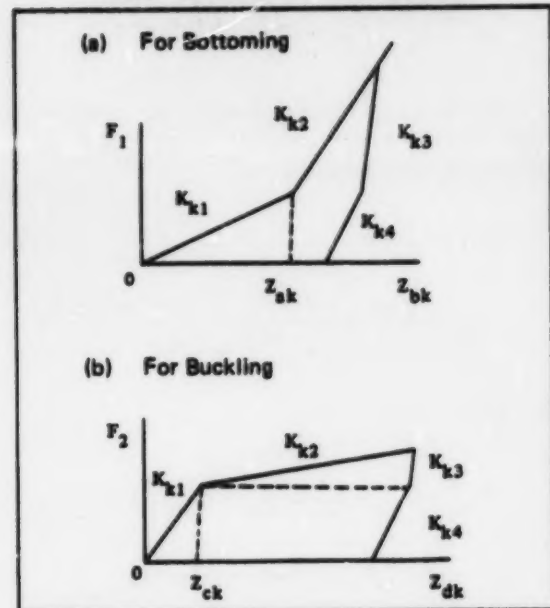


FIGURE 4

When compression deformation is on the increase:

$$(a) \quad Z_{mk} > Z_{bk} > 0$$

$$F_k = K_{k1} \cdot Z_{bk}$$

$$(b) \quad Z_{bk} > Z_{mk}$$

$$F_k = K_{k1} \cdot Z_{mk} - K_{k2}(Z_{bk} - Z_{mk})$$

When the compression deformation is on the decrease:

$$(a) \quad Z_{\max k} > Z_{mk}$$

$$F_k = K_{k1} \cdot Z_{\max k} + K_{k4}(Z_{bk} - Z_{\max k})$$

$$(b) \quad Z_{\max k} > Z_{mk} \text{ and } Z_{bk} > Z_{ck}$$

$$F_k = K_{k1} \cdot Z_{mk} + K_{k2} \cdot Z_{\max k} + K_{k3}(Z_{bk} - Z_{\max k})$$

$$(c) \quad Z_{\max k} > Z_{mk}, Z_{sk} < Z_{ck}$$

$$F_k = K_{k1} \cdot Z_{mk} + K_{k2} \cdot Z_{\max k}$$

$$+ K_{k3}(Z_{ck} - Z_{\max k}) + K_{k4}(Z_{bk} - Z_{ck})$$

Where

$$Z_{ck} = -\frac{K_{k2}}{K_{k3}} (Z_{\max k} - Z_{mk}) + Z_{\max k}$$

Incidentally, the amount of compression deformation at the cornered portion and panel portion is presented as follows:

• Cornered portion

$$Z_{ck} = \frac{(X_{sk} - X_{cl}) \sin \theta_i - (Y_{sk} - Y_{cl}) \cos \theta_i}{\sin(\theta_i - \beta_k)}$$

• Panel portion

(a) at the gravity center

$$Z_{jmi} = (X_{jm} - X_i) \sin \beta_{jm} - (Y_{jm} - Y_i) \cos \beta_{jm}$$

(b) at the pin-joint, head top and heel.

$$Z_{jmi} = (X_{jm} - X_{cl}) \sin \beta_{jm} - (Y_{jm} - Y_{cl}) \cos \beta_{jm}$$

Friction Forces At The Vehicle's Front

The friction force at the vehicle's front was supposed to be in proportion to the compression force F_r which acts on the pedestrian.

However, its friction coefficient F_k was subjected to a limitation, as a function of the relative velocity V_{bk} at the contact point of the vehicle and pedestrian. The Figure 5 presents the limit.

$$(1) \quad V_{pk} > V_{bk} > -V_{pk}$$

$$F_{pk} = \mu_{\max k} \cdot$$

$$F_{pk} = \mu_{\max k} \cdot \frac{V_{bk}}{V_{pk}} \cdot F_k$$

$$(2) \quad V_{bk} > V_{pk}$$

$$F_{rk} = \mu_{\max k} \cdot F_k$$

$$(3) \quad V_{bk} < -V_{pk}$$

$$F_{rk} = -\mu_{\max k} \cdot F_k$$

FRICITION COEFFICIENT AT THE VEHICLE'S FRONT

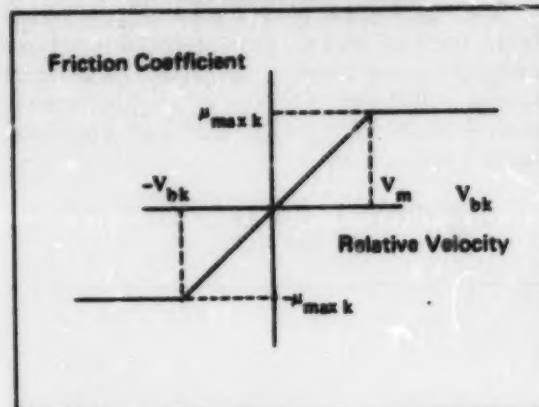


FIGURE 5

The relative velocity is as follows:

• For cornered portion

$$V_{bk} = (\dot{X}_{cl} - \dot{X}_{bk}) \sin \beta - (\dot{Y}_{cl} - \dot{Y}_{bk}) \cos \beta_k$$

$$- \rho_{bk} \theta_i \cos(\theta_i - \beta_k)$$

• For panel portion

(a) At the gravity center

$$V_{jmi} = (\dot{X}_{jm} - \dot{X}_i) \cos \beta_{jm} + (\dot{Y}_{jm} - \dot{Y}_i) \sin \beta_{jm}$$

(b) At the pin-joint, hood top and heel

$$V_{jmi} = (\dot{X}_{jm} - \dot{X}_{cl}) \cos \beta_{jm} + (\dot{Y}_{jm} - \dot{Y}_{cl}) \sin \beta_{jm}$$

Spring Characteristics And Friction Coefficient At The Contact Points Of Road Surface And Heel

As shown in the Figure 6, the contact points with road surface and the spring characteristics were studied with attention being paid so that the heel would not sink into the road surface. In addition, restoration corresponding to the amount of initial was permitted.

With initial heel position being represented by Y_c and its position at the moment of detachment from the road surface by Y_c :

$$(1) \quad Y_{csm} > Y_{cs} > Y_{cso}$$

$$F_t = k_t(Y_{cs} - Y_{cso})$$

$$(2) \quad Y_{cso} > Y_{cs} > 0$$

$$F_t = k_t \left\{ (Y_{csm} - Y_{cso}) + \frac{Y_{cso} - Y_{cs}}{Y_{cs}} \right\}$$

SPRING CHARACTERISTICS AT THE GROUNDING POINT

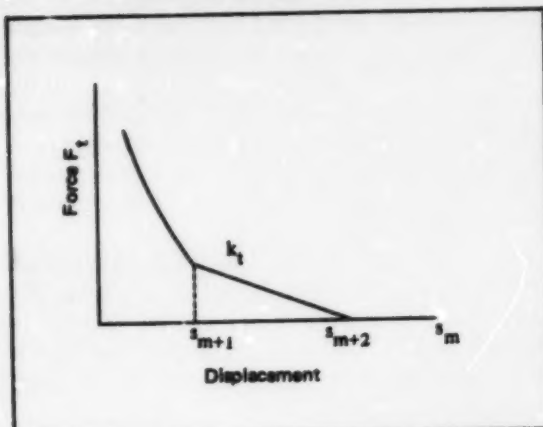


FIGURE 6

Where,

$$k_t = \frac{\sum_{[2]}^s m_j \cdot G}{Y_{csm} - Y_{cso}}$$

In addition, the same friction coefficient was applied, as in the case of the vehicle's front portion.

CHARACTERISTIC VALUE OF EACH PORTION AND METHOD OF COLLISION EXPERIMENT

Characteristic Value Of Each Portion

For the measurement, mass, moment of inertia and position of the gravity center of a human body employed for numerical computation, our measured data on a dummy of the 50 percentile Japanese adult male were employed. And for the characteristics of the joints, Smith's data were used.

In addition, the spring characteristics of the vehicle's body were assumed on the basis of the data obtained from simple experiments (see appendix).

Figure 7 indicates the experiment value of the front bumper's spring characteristics. They are the

test results of the front bumper and bumper stay. The bumper stay is easily bent. However, somewhat higher value was employed for the bumper stay because the spring characteristics of the bumper portion were assumed to have higher numerical value in cars where considerably rigid structures are placed right in the back of the bumper.

THE SPRING CHARACTERISTICS OF THE FRONT BUMPER

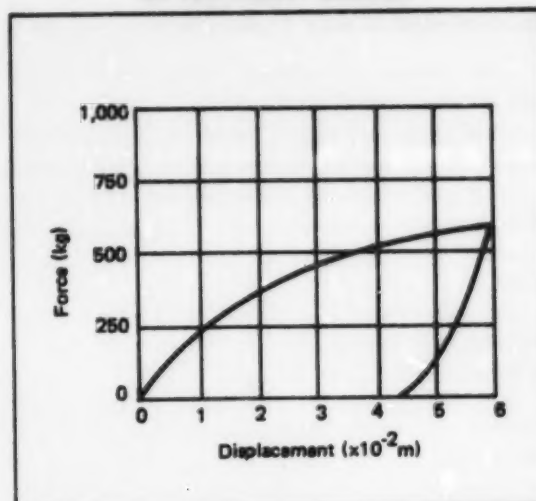


FIGURE 7

THE SPRING CHARACTERISTICS OF THE UPPER SURFACE OF HOOD

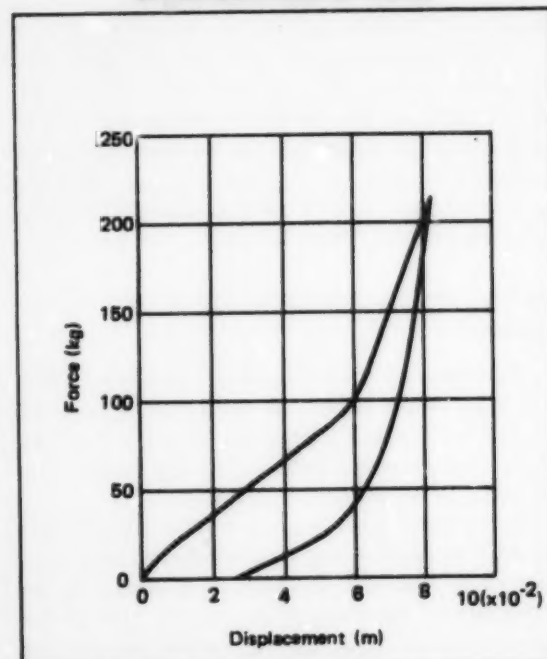


FIGURE 8

Figure 8 indicates the spring characteristics of the upper surface of the hood nearly at its center. The numerical computation was based on this numerical value for the whole hood.

Meanwhile, the spring characteristics of the leading edge of the hood and the radiator grill were substituted for by the spring characteristics of the front bumper and the upper surface of the hood.

The Method Of Collision Experiment

The method of collision experiment will be discussed only briefly herein.

First a 50 percentile dummy of Japanese adult male was employed and the dummy was provided with a hook at the head top and hanged by a 1-inch wire. The hook was so designed as to release the dummy in response to a slightest movement at the time of collision.

An accelerometer was fitted to the dummy to measure the impact acceleration at the time of collision.

Incidentally, attempt was made to put abrupt brake on the vehicle the moment it gets in touch with the dummy.

CORRESPONDENCE OF THE NUMERICAL VALUES AND EXPERIMENT DATA

The conditions of the collision being discussed here were set as follows:

A vehicle strikes a pedestrian from behind at two speeds - 18km/h and 36km/h. And the car was supposed to put on emergency braking, the moment it contacts the pedestrian. In the numerical computation, deceleration was set at 0.65g. And the nose down phenomenon which develops as the result of emergency braking was ignored.

On The Behavior Of The Pedestrian At The Time Of Collision

According to the computation obtained on the behaviors of the dummy at the impact velocity of 18km/h and 36km/h, the initial impact is from the bumper which strikes the low leg. Slightly later, the leading edge of the hood strikes the hip.

In the computation, each portion of the body was assumed as a part of single rod, connecting each joint, and meat was not considered. However, in an experiment using dummy, the leading edge of the hood tends to strike the hip earlier than the leg because the projection of hip's contour is greater than that of a leg.

Then, the lower half of the dummy begins to be pressed by front bumper, hood tip and radiator grill, in that order, and its legs detouch off the ground.

Being bent, the legs begin to bite into the bumper, while the upper half of the body starts bending over the hood.

The upper half of the body rotates further about the leading edge of hood. Then according to the computation results, the lower half of the body starts separating from the front bumper and radiator grill. However, in the experiment, the lower half of the body continued its contact with the front bumper and radiator grill. It is considered the discrepancy was caused either because the spring characteristics of the H point which were employed for computation were estimated to be greater than those of the dummy or because the H point had landed over the hood as the result the H point was located at a higher position than the hood height.

After the above process, the head and waist of the dummy strike the upper surface of the hood. The head takes 140 msec at the impact velocity of 18km/h and 75 msec at the impact velocity of 36km/h, respectively, to strike the hood upper surface.

And they are little shorter than experiment results which show 170 msec and 85 msec respectively. The cause of the difference is not clear. However, it is assumed that since the arms were ignored in the computation, smaller quickening of the phenomenon.

In the computation, the head is found to incline forward after the body hits the hood as hard as it reaches a 90 degree against the upper torso. However, the phenomenon was not so conspicuous in the experiment. The discrepancy seems to indicate that there were some problems in the hypothesis of the spring characteristics of the hood upper surface.

Since the vehicle was in the process of emergency stoppage, the dummy begins to drop in forward direction after sliding on the hood.

Impact Acceleration Of Pedestrian

Figure 9 presents a comparison between computation results and experiment results regarding the forward and backward acceleration of the dummy's hip and head. The coordinates system was based on the standards of the dummy.

The forward and backward acceleration of hip contains some vibration component in the experiment.

However, the basic wave patterns at the impact velocity of 18km/h and 36km/h are considerably

ACCELERATION OF DUMMY VERSUS TIME AT 18 AND 36 km/h IMPACT VELOCITY

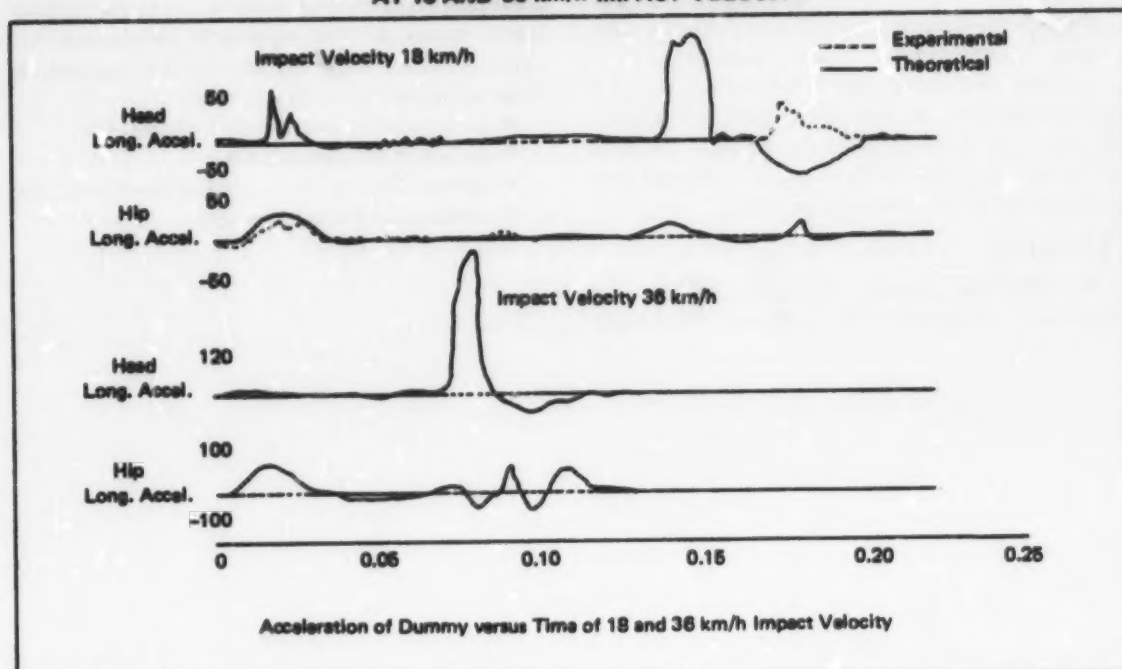


FIGURE 9

similar. Incidentally, considerably large vibration component is contained in the experiment waves at the impact velocity of 36km/h around 20 msec. The phenomenon is attributable to some difficulties in hook release systems at the dummy head top. Thus, large vibration component is present in the acceleration waves of the head at the velocity of 18km/h and 36km/h.

As far as the forward and backward acceleration of the head is concerned, large acceleration develops when the head strikes the upper surface of the hood at both 18km/h and 36km/h. The peak values obtained by computation are two to four times larger than the experiment values. This seems to be caused by problems present in the hypothesis of spring characteristics of the neck or hood as described earlier relative to the behavior of the dummy.

Summary Of The Correspondence Between Numerical Computation And Experiment

Numerical computation has so far been attempted for the cases where a car strikes a pedestrian from behind, employing a model with seven degrees of freedom and the results have been compared with the experiment results. Summarized points are:

- With regard to the behavior, they coincide fairly well as far as the first half of the colliding process is concerned. However, in the second half, considerable discrepancy presents itself, including a case where lower half of the body detaches from the front portion of the vehicle. In addition, after the head strikes the upper surface of the hood, it bounces back and either leans forward against the upper torso or develops considerably larger values than the experiment values. The former phenomenon is attributable to the problems present in the hypothesis of the spring characteristics of H point. At the same time, it is assumed that the location of the H point from the ground may be in the vicinity of the leading edge of hood top, delicately affecting the behavior after the collision — if the pedestrian gets over the hood or not. The latter phenomenon, on the other hand, may be attributable to the problems present in the hypothesis of the spring characteristics of the neck or the upper surface of the hood.
- With regard to the forward and backward acceleration of the hip and head of the dummy, the findings coincide fairly well as far as the collision of the hip with the vehicle's front portion is concerned. However, the computation results

present greater values for the case where the head strikes the upper surface of the hood. The discrepancy is considered resultant from the same cause as explained in the case of behavior gap.

As indicated above, the numerical computation and experiments offer some differences, but they are believed to be solved by clarifying the basic data such as the spring characteristics. Thus, it is assumed that modeling, itself, is a reasonable attempt.

IN CLOSING

As discussed above, now that validity of numerically analyzing the collision phenomena

between pedestrians and validity using models is confirmed, it is desired from now on that studies based mainly on the numerical computation are advanced on the following subjects as a contribution to the safety measures of pedestrians:

- Collision phenomena from front and side,
- Shape of the vehicle's front,
- Spring characteristics of the vehicle's front, and
- Impact at the time of landing.

APPENDIX

(1) MATRIX

$$(A) = \begin{bmatrix} I_1 + M_1 \rho_1^2 & M_1 \rho_1 R_2 \cos(\theta_1 - \theta_2) & M_1 \rho_1 R_3 \cos(\theta_1 - \theta_3) \\ M_1 \rho_1 R_2 \cos(\theta_2 - \theta_1) & I_2 + M_1 R_2^2 + M_2 \rho_2^2 & (M_1 R_2 + M_2 \rho_2) R_3 \cos(\theta_2 - \theta_3) \\ M_1 \rho_1 R_3 \cos(\theta_3 - \theta_1) & (M_1 R_2 + M_2 \rho_2) R_3 \cos(\theta_3 - \theta_2) & I_1 + (M_1 + M_2) R_2^2 + M_3 \rho_3^2 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ -M_1 \rho_1 \sin \theta_1 & -(M_1 R_2 + M_1 \rho_2) \sin \theta_2 & -\{(M_1 + M_2) R_2 + M_2 \rho_2\} \sin \theta_3 \\ M_1 \rho_1 \cos \theta_1 & (M_1 R_2 + M_2 \rho_2) \cos \theta_2 & \{(M_1 + M_3) R_1 + M_3 \rho_3\} \cos \theta_3 \\ \\ 0 & 0 & -M_1 \rho_1 \sin \theta_1 \\ 0 & 0 & -(M_1 R_2 + M_2 \rho_2) \sin \theta_2 \\ 0 & 0 & -\{(M_1 + M_2) R_2 + M_2 \rho_2\} \sin \theta_3 \\ I_4 + M_4 (R_4 - \rho_4)^2 + M_5 R_4^2 & M_5 R_4 (R_5 - \rho_5) \cos(\theta_4 - \theta_3) & \{M_4 (R_4 - \rho_4) + M_3 R_4\} \sin \theta_4 \\ M_5 R_4 (R_5 - \rho_5) \cos(\theta_3 - \theta_4) & I_5 + M_5 (R_5 - \rho_5)^2 & M_5 (R_5 - \rho_5) \sin \theta_5 \\ \{M_4 (R_4 - \rho_4) + M_3 R_4\} \sin \theta_4 & M_5 (R_5 - \rho_5) \sin \theta_5 & M_1 + M_2 + M_3 + M_4 + M_5 \\ -\{M_4 (R_4 - \rho_4) + M_3 R_4\} \cos \theta_4 & -M_5 (R_5 - \rho_5) \cos \theta_5 & 0 \\ \\ & & M_1 \rho_1 \cos \theta_1 \\ & & (M_1 R_2 + M_2 \rho_2) \cos \theta_2 \\ & & \{(M_1 + M_3) R_1 + M_3 \rho_3\} \cos \theta_3 \\ & & -\{M_4 (R_4 - \rho_4) + M_3 R_4\} \cos \theta_4 \\ & & -M_5 (R_5 - \rho_5) \cos \theta_5 \\ & & 0 \\ & & M_1 + M_2 + M_3 + M_4 + M_5 \end{bmatrix}$$

$$(B) = \begin{bmatrix} 0 & -M_1 \rho_1 R_2 \sin(\theta_1 - \theta_2) & -M_1 \rho_3 R_3 \sin(\theta_1 - \theta_3) \\ -M_1 \rho_1 R_2 \sin(\theta_2 - \theta_1) & 0 & -(M_1 R_1 + M_2 \rho_2) R_1 \sin(\theta_2 - \theta_1) \\ -M_1 \rho_1 R_3 \sin(\theta_3 - \theta_1) & -(M_1 R_1 + M_2 \rho_2) R_1 \sin(\theta_2 - \theta_1) & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ M_1 \rho_1 \cos \theta_1 & (M_1 R_1 + M_1 \rho_2) \cos \theta_2 & \{(M_1 + M_2) R_3 + M_1 \rho_3\} \cos \theta_3 \\ M_1 \rho_1 \sin \theta_1 & (M_1 R_2 + M_2 \rho_2) \sin \theta_2 & \{(M_1 + M_1) R_3 + M_1 \rho_3\} \sin \theta_3 \end{bmatrix}$$

$$\begin{bmatrix} 0 & 0 \\ 0 & 0 \\ 0 & 0 \\ 0 & -M_5 R_4 (R_5 - \rho_3) \sin(\theta_4 - \theta_3) \\ -M_5 R_4 (R_5 - \rho_3) \sin(\theta_3 - \theta_4) & 0 \\ -\{(M_1 R_4 - \rho_4) + M_3 R_4\} \cos \theta_4 & -M_3 (R_3 - \rho_3) \cos \theta_3 \\ -\{M_4 (R_4 - \rho_4) + M_4 R_4\} \sin \theta_4 & -M_3 (R_3 - \rho_3) \sin \theta_3 \end{bmatrix}$$

$$(C) = \begin{bmatrix} -1 & 0 & 0 & 0 \\ 1 & -1 & 0 & 0 \\ 0 & 1 & -1 & 0 \\ 0 & 0 & 1 & -1 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

$$(D) = \begin{bmatrix} -\rho_4 \sin(\theta_1 - \beta_1) & 0 & 0 & 0 & 0 \\ -R_1 \sin(\theta_2 - \beta_1) & -\rho_4 \sin(\theta_2 - \beta_2) & 0 & 0 & 0 \\ -R_3 \sin(\theta_3 - \beta_1) & -R_3 \sin(\theta_3 - \beta_2) & -\rho_4 \sin(\theta_3 - \beta_3) & 0 & 0 \\ 0 & 0 & 0 & (R_4 - \rho_4) \sin(\theta_1 - \beta_4) & R_4 \sin(\theta_1 - \beta_5) \\ 0 & 0 & 0 & 0 & (R_5 - \rho_4) \sin(\theta_5 - \beta_5) \\ \cos \beta_1 & \cos \beta_2 & \cos \beta_3 & \cos \beta_4 & \cos \beta_5 \\ \sin \beta_1 & \sin \beta_2 & \sin \beta_3 & \sin \beta_4 & \sin \beta_5 \end{bmatrix}$$

$$(E) = \begin{bmatrix} \rho_4 \cos(\theta_1 - \beta_1) & 0 & 0 & 0 \\ R_1 \cos(\theta_2 - \beta_1) & \rho_2 \cos(\theta_2 - \beta_2) & 0 & 0 \\ R_1 \cos(\theta_1 - \beta_1) & R_3 \cos(\theta_1 - \beta_1) & \rho_1 \cos(\theta_1 - \beta_1) & 0 \\ 0 & 0 & 0 & -(R_1 - \rho_1) \cos(\beta_2 - \beta_2) \\ 0 & 0 & 0 & 0 \\ -\sin \beta_1 & -\sin \beta_2 & -\sin \beta_3 & -\sin \beta_4 \\ \cos \beta_1 & \cos \beta_2 & \cos \beta_3 & \cos \beta_4 \\ & & & 0 \\ & & & 0 \\ & & & 0 \\ & & & -R_1 \cos(\theta_2 - \beta_3) \\ & & & -(\rho_3 - \rho_4) \cos(\theta_2 - \beta_3) \\ & & & -\sin \beta_5 \\ & & & \cos \beta_5 \end{bmatrix}$$

$$(F) = \begin{bmatrix} 0 & 0 \\ 0 & 0 \\ 0 & 0 \\ -R_4 \cos \theta_4 & \rho_4 \sin \theta_4 \\ R_4 \cos \theta_5 & \rho_3 \sin \theta_5 \\ 0 & 1 \\ 1 & 0 \end{bmatrix} \quad (G) = \begin{bmatrix} -M_1 \rho_1 g \cos \theta_1 \\ -(M_1 R_1 + M_2 \rho_2) g \cos \theta_2 \\ -(M_1 + M_2) R_3 + M_2 \rho_3 \quad g_1 + \theta_3 \\ M_4 (R_4 - \rho_4) + M_1 R_4 \quad g_4 + \theta_4 \\ M_2 (R_3 - \rho_4) g \cos \theta_3 \\ 0 \\ -(M_1 + M_2 + M_3 + M_4 + M_5) g \end{bmatrix}$$

(2) SPECIFICATION AND CHARACTERISTICS

Table 1
Specification of the Dummy

i	M(kg · s ² /m)	I(kg · m · s ²)	R(m)	ρ(m)
1 Head	0.536	0.00332	0.201	0.118
2 Torso	1.685	0.0174	0.410	0.242
3 Waist	0.943	0.0111	0.100	0.075
4 Thigh	1.210	0.0115	0.405	0.230
5 Lower Leg	0.796	0.0212	0.455	0.237

Table 2
The Characteristics at Joints

i	θ_u (deg)	θ_d (deg)	k_{su} (kg m/rad ²)	k_{sd} (kg m/rad ²)	$\dot{\theta}$ (deg/s)	τ_r max
1 Neck	40	- 20	30	30	20	1.5
2 Abdomen	5	- 15	16.41	16.41	20	3.6
3 Hip	5	-120	16.41	16.41	20	3.6
4 Knee	120	0	1215	1215.2	20	1.2

Table 3
Specification of the Vehicle and Spring Characteristics

	β (deg)	R_k (m)	K_1 (kg/m)	K_2 (kg/m)	K_3 (kg/m)	K_4 (kg/m)
Front Bumper	0		2000	1000	2000	2000
Hood Tip	15		2000	1000	2000	2000
Radiator Grill	95	0.424	3000	10000	20000	2000
Hood Surface	175	0.972	3000	10000	20000	2000

Experiments On Behaviors Of A Pedestrian In A Collision With A Motor Vehicle

Japan Automobile Manufacturers Association, Inc.

GENERAL

The objectives of the present experimental study can be summarized in the following manner:

- Study of the behavior of a human body in collision
- Study of shock absorption by employment of energy-absorbing materials on the car
- Study of effect of modified front design for reduction of injuries
- Study of shapes of side guard of a heavy truck and effects of it

Outlined results and conclusions can be summarized in the following manner:

- A passenger car decelerated by the emergency brake is not likely to run over a man after collision against him.
- For an adult, the direct percussion affects heavily on his leg and secondarily, a severe shock is given to his head upon striking against the road.
- For a child, the primary percussion affects his whole body.
- When the front bumper is of an energy-absorbing type, considerable favorable effect can be obtained for reducing the percussion of the leg.
- By proper modification of the front structure, some effect can be obtained to improve the sideward repelling and shock reduction. However, sideward repelling leads to the possibility of being run over by another vehicle, and accordingly further studies are required with due consideration of the result as mentioned above.
- Poor result was obtained in effective reduction of head percussion on the road; this particular percussion is fatal and this problem remains as the most difficult one to be solved in the future.
- A side guard on a heavy truck contributes effectively to reduce remarkably the chance of severe injury by a rear wheel.

PROCEDURES OF CONDUCTING EXPERIMENTS

Objects and Methods of Experiments

In conducting experiments of collisions between the pedestrian and the motor vehicle, for fathoming deeply into the true status of this particular phenomenon, a considerable number of contributing factors must be involved, producing an immense number of cases by combination of these factors.

For example, the contributing factors run as follows:

- Passenger cars (standard-type, medium-type, small-type, sport car, midjet-type)
- Trucks (standard-type, medium-type, small-type, towing-truck, trailer)
- Dummies (aged, adult, child, infant)
- Collision velocities (10 km/h up)
- Brake systems (braking immediately before the collision, simultaneous with the collision, after the collision, emergency braking, light braking, without braking)
- Position of collision, posture of victim (located to face front center of the vehicle, righthand corner, lefthand corner, facing sideways to the vehicle, facing away from the vehicle)
- Conditions of road (paved, non-paved)

If all the above contributing factors are to be considered, the scope of the experiments would be excessively exhaustive, leading to almost prohibitively large-scaled experiments. In the present study, a few of the most outstanding combinations were taken up in order to place strong emphasis on analysis of actual phenomena of the collisions and also on evaluation of effects of the corrective measures.

Primarily, for the passenger cars, a combination of the factors was considered, as shown in Table 1.

For heavier trucks, grown-up and child dummies were employed (right-angle, slow-speed turning) for the study of effectiveness of the side guard and for confirmation of necessity of this particular guard.

Table 1

Methods of Experiments
(Showing combination of contributing factors)

Vehicle Classification			Vehicle Specifications	Collision Velocity	Braking	Dummy	Direction and position of Dummy
Medium-type passenger car (2,000 cc Class)	Small-type passenger car (1,000 cc Class)	Midjet-type passenger car (360 cc Class)	Conventional Specifications	10-40km/h (for each 10km/h)	Emergency braking simultaneous with collision	Adult dummy	Dummy in crossing motor highway
			Modified Shape		or	and	and
			Energy-Absorbing type		Emergency braking immediately before collision	Child dummy	located at the center or the end of vehicle
Equipped with a front bumper							

Table 2

Experimental Vehicles and Dummies

Experiment No.	Type of Vehicle	Conventional design	Specially designed front end	Shock-absorbing bumper	Shock-absorbing bonnet	Equipped with side guard	Dummy	
							Adult male	Child
1	Medium-type passenger car (Nissan Cedric)						American adult male 50 percentile made by aierraatan Height: 167cm Weight: 85kg	Child of 4-5 years old, made by Expro. Height: 100cm Weight: 17kg
2	Small-type passenger car (Iauru Bellet)						Japanese adult male 50 percentile made by Itoh Seiki Height: 167cm Weight: 61kg	
3	Midjet-type (Honda N360)							
4	Heavy truck (Mitaubishi Fuso)						Japanese adult male 50 percentile made by Expro. Height: 167cm Weight: 61kg	

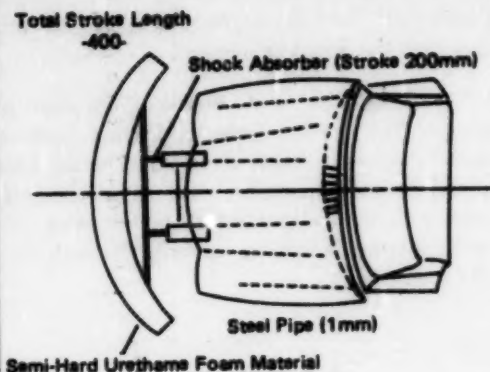
Table 3
Experiment Number and Experiment Specifications

Experiment No.	Company assigned	Specifications	Velocity	Position of Dummy	
				Grown-up	Child
1	Isuru	Conventional	20	Center	End
2	Honda	Conventional	20	End	End
3	Nissan	Special shape	10	Center	End
4	Isuru	Conventional	30	Center	End
5	Honda	Absorbing-type	30	End	End
6	Nissan	Special shape	25	End	Center
7	Isuru	Conventional	40	Center	End
8	Nissan	Special shape	40	End	Center
9	Mitou-biahi	Equipped with a single side guard	15	End	—
10	Nissan	Absorbing-type	10	Center	End
11	Honda	Conventional	10	End	End
12	Isuru	Absorbing-type	20	Center	End
13	Nissan	Absorbing-type	25	Center	End
14	Isuru	Absorbing-type	30	Center	End
15	Honda	Absorbing-type	20	End	End
16	Nissan	Absorbing-type	40	Center	End
17	Isuru	Absorbing-type	40	Center	End
18	Honda	Conventional	30	End	End
19	Nissan	Conventional	10	Center	End
20	Nissan	Conventional	25	End	Center
21	Honda	Absorbing-type	40	End	End
22	Nissan	Conventional	40	Center	End
23	Mitou-biahi	Equipped with two side guards	15	—	End
24	Mitou-biahi	Equipped with a single side guard	15	—	End
25	Mitou-biahi	Without side guard	15	—	End
26	Mitou-biahi	Without side guard	15	End	—

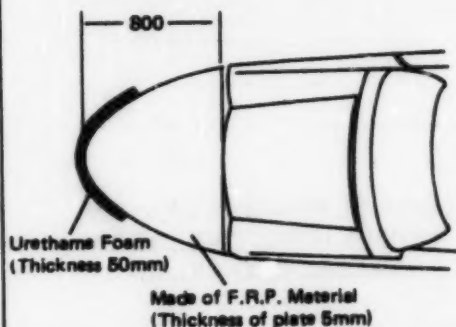
Location of Experiments - Yatabe Automobile
Highspeed Testing Course, Ibaragi Prefecture, Japan
Daily Schedules of Experiments From 7 April to
13 April, 1988

Design Specification of Corrected Vehicles

Medium-type Passenger Car

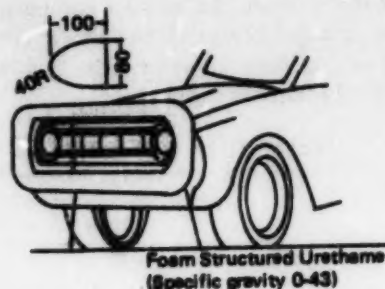


Medium-type Experiment Passenger Car
with shock-absorbing front bumper
(Height of bonnet: 700mm)



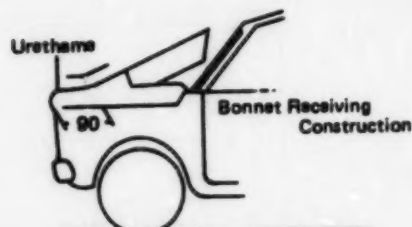
Medium-type Experimental Passenger Car
with specially designed front end
(Height of bonnet: 790mm)

Small-type Passenger Car

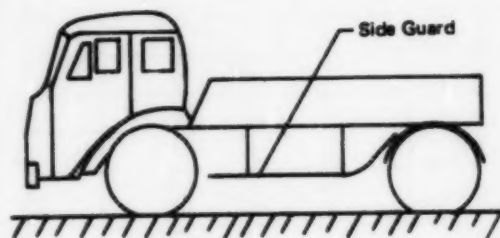


Small-type Experimental Passenger Car
with Shock-Absorbing Bumper

Midget-type 4-wheeled Passenger Car (Height of Bonnet: 500 mm)



Midget-type Experimental Passenger Car
with Shock-Absorbing Bonnet
(Height of bonnet: 800mm)



Heavy-type Truck with Side Guard

DESCRIPTION OF RESULTS OF EXPERIMENTS

Behavior of Dummies

Behavior of Adult Dummies — The behavior of an adult dummy from the moment of initiation of collision through to that of landing on the ground was found to take approximately the following process as illustrated in Figure 1.

BEHAVIOR OF DUMMY

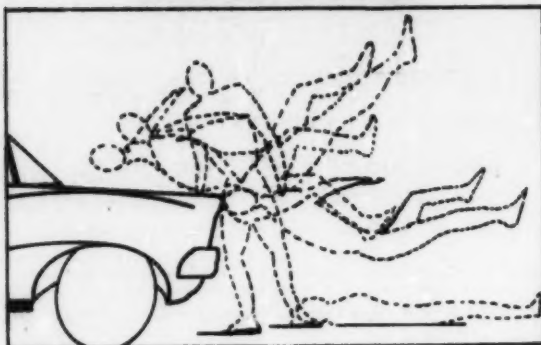


FIGURE 1

The attached drawings 1, 2 and 3 represent practical examples of collisions of the conventional motor vehicles against dummies, showing the behaviors of the dummies and acceleration curves of individual parts.

Behavior of Child Dummies — In the case of a child dummy, it is first pushed forward by the front surface of the vehicle and it falls down on the ground maintaining an upright posture, showing a comparatively simple behavior. Time from the initiation of the collision to landing on the ground lasts only half the time corresponding to the time interval from the grown-up dummy.

Collision Velocity and Repelled Distance of Dummy — The repelled distance (distance between the initial standing position of a dummy to the final position of the dummy to which it is expelled) increases with the collision velocities. (However, the repelled distance varies in accordance with the braking conditions.)

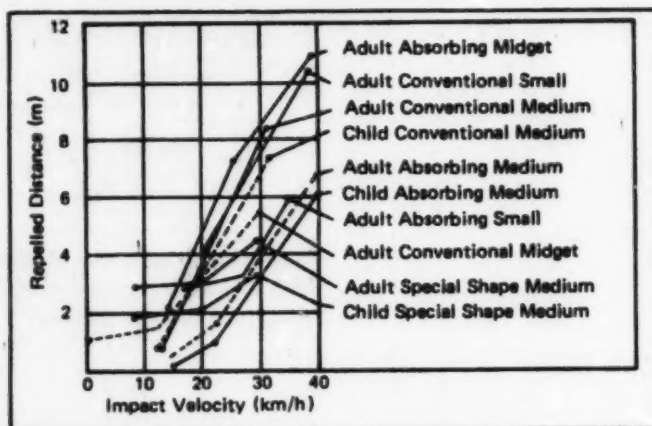


FIGURE 2

REPelled DISTANCE VERSUS IMPACT VELOCITY

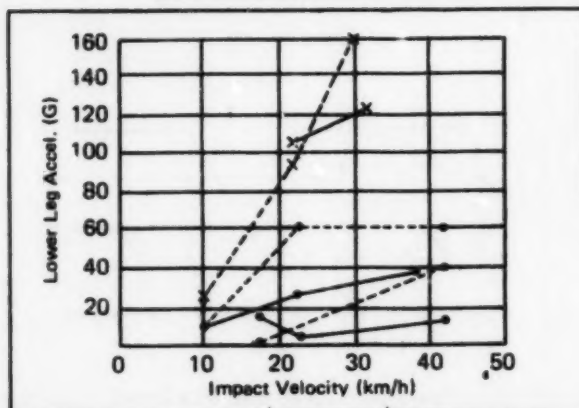


FIGURE 3

LOWER LEG ACCELERATION VERSUS IMPACT VELOCITY (3M SEC ONO-AXIAL)

—x—x—	Adult	} Conventional
- - -x- - -	Child	
—o—o—	Adult	} Shock Absorbing
- - -o- - -	Child	
—•—•—	Adult	} Special Shape
- - -•- - -	Child	

Collision Accelerations (according to vehicle classification)

Medium-type Passenger Car

• Acceleration values on lower leg

Results obtained for the vehicles equipped with a specially shaped front end and with a shock absorbing bumper.

In the case of the acceleration of a point on the lower limb, lower values are obtained for both vehicles equipped with specially shaped front end and with shock absorbing bumper than for the conventional vehicle for each collision velocity.

Specially low G values obtained for the experimental vehicle equipped with the specially shaped front end are presumed to be attributable to lower collision point of the bumper.

• Acceleration values on head

In the case of the G values for the head, no distinctive difference was observed as in the case of the lower limb, however, some significant difference was observed in the vehicle equipped with the specially shaped front end.

(Additionally, extraordinarily high G values on the adult dummy for the vehicle with the specially shaped front end at the collision velocity of 21 km/h is attributable to the fact that the dummy struck against the front windshield pillar.)

HEAD ACCELERATION VERSUS IMPACT VELOCITY (FACING TO THE VEHICLE)

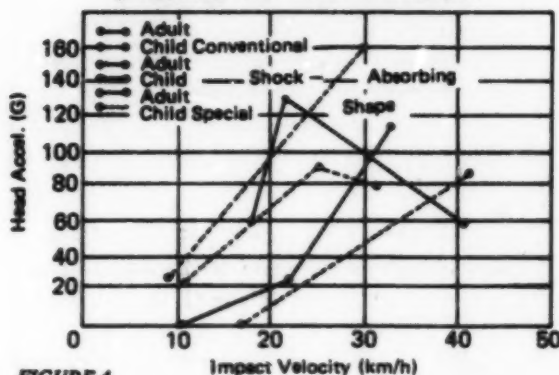


FIGURE 4

Small-type Passenger Car Equipped With the Energy-absorbing Bumper

• Acceleration values on waist and leg

In the case of the adult dummy, low values were obtained for the vehicle with the energy-absorbing bumper at the collision velocity of below

HIP AND LEG ACCELERATION VERSUS IMPACT VELOCITY

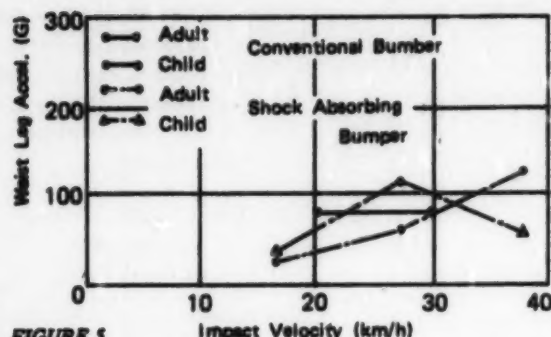


FIGURE 5

approximately 30 km/h. However, for higher velocities, approximately the same values were obtained as those for the conventional vehicles.

In the case of the child dummy, only few observations and measurements were taken, however, lower G values were obtained always for the vehicle equipped with the energy-absorbing bumper.

• Acceleration values on head

In the case of adult dummy, higher values were obtained for the vehicle with the energy-absorbing bumper than for the conventional vehicles. On the other hand, in the case of child dummy, lower G values were obtained for all the vehicles with the energy-absorbing bumper, regardless of the vehicle

HEAD ACCELERATION VERSUS IMPACT VELOCITY

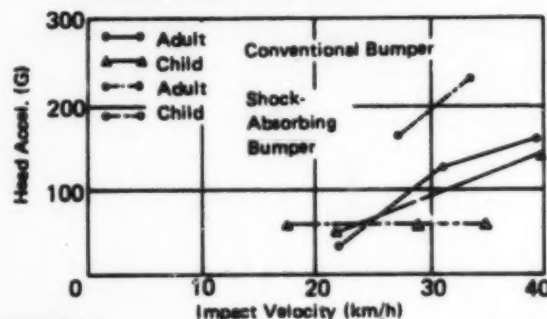


FIGURE 6

velocities. In comparison with the adult dummy striking its head against the bonnet, the child dummy employed in this experiment contacted directly its head on the energy-absorbing type bumper, leading to presumably better results on the part of the child dummy.

Midget-type Passenger Car with the Energy-absorbing Bonnet - The acceleration

generated when the vehicle strikes against the dummy is lower in the case of the vehicle with the energy-absorbing type bonnet in a small measure and no improvement even by 10 km/h, when expressed in the vehicle velocity, has been observed. Further, the repelled distance and the acceleration at the instant when the dummy landed on the road surface is oppositely observed to take higher values.

LEG ACCELERATION VERSUS IMPACT VELOCITY

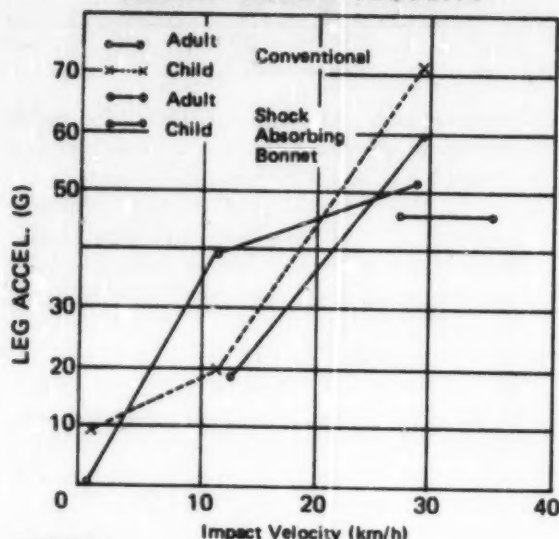


FIGURE 7

HEAD ACCELERATION VERSUS IMPACT VELOCITY

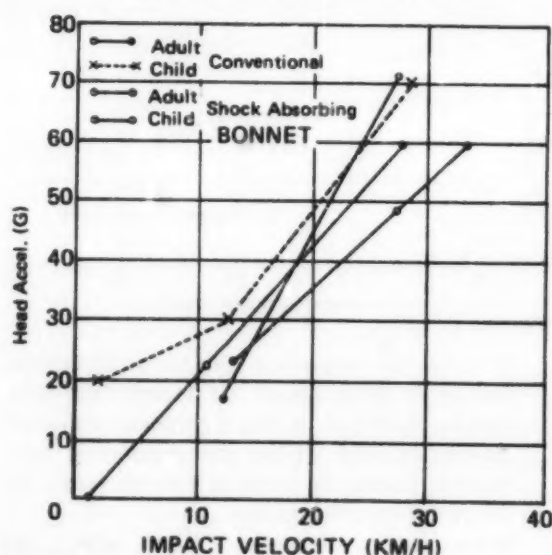


FIGURE 8

Comparison of Results - In the case of experiment on the leg, the vehicle with energy-absorbing bumper, in the lower range of velocities, shows a significant difference compared with the conventional vehicle.

Especially, when the medium-type vehicle with the energy-absorbing bumper is subjected to measurement, the acceleration values, in the range of lower velocities, shows better results by approximately 30% as compared with the conventional vehicle.

As far as the vehicle equipped with special shape bumper is concerned, better effect by approximately 40% was obtained, caused by lowering the position of contact along the leg.

In the case of experiment on the head, all the vehicle, regardless of the difference of model and no significant variation was observed in the absolute values.

Collision against Road

The conditions of collision against road depend upon the posture of the dummy when it landed on the ground and other related factors. Accordingly the relative relationship with the collision velocity has not yet been clarified. The result should be examined upon confirmation of the reproducibility of the measurements.

As shown in Figure 9, the acceleration values in collision against road turn out very high.

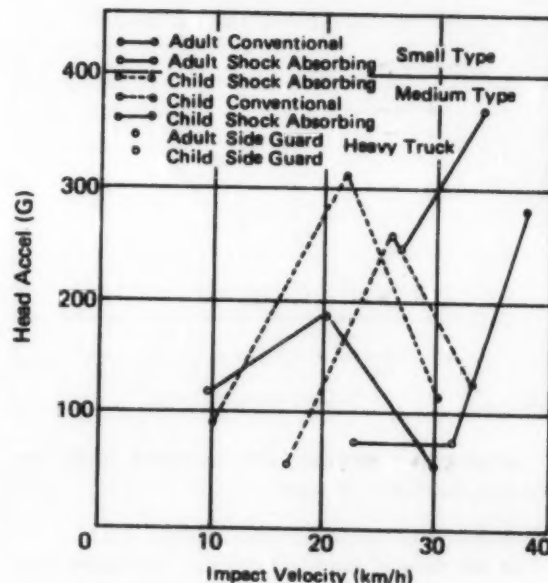
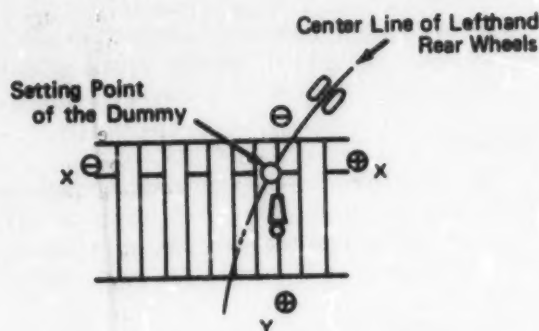


FIGURE 9

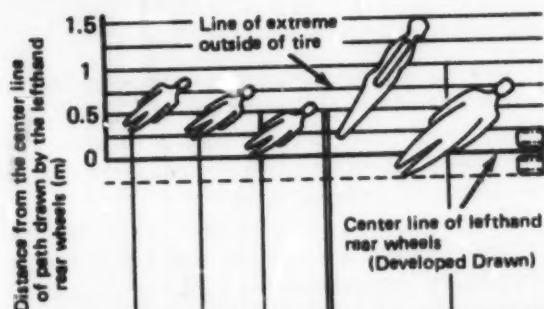
Experiments on Side Guard

Existence of the side guard affects the position of head and breast in the range of 40 cm and 60 cm. This much difference affects appreciably the probable chance of being run over by the rear wheels.



FOR DETAILED DESCRIPTION,
REFERENCE IS MADE TO THE
ATTACHED DRAWING 4.

Expelled distance from the setting point of the dummy	S direction	Y direction
Breast (mm)	+0.10	+0.90
Head (mm)	+0.10	+1.25



Experiment Number	23	24	25	9	26
Side Guard	2	1	Without	1	Without
Dummy	Child			Adult	

CONCLUSIONS AND EVALUATIVE COMMENTS

General

In the present experiments:

- In order to obtain the clearest view of the effect, some drastic modifications were made on the

conventional design of the vehicles, even something short of unrealistic modifications.

- Whereas the experiments were performed by different groups in a cooperative manner, a slight variation was found in the specifications of the vehicle and in the methods of conducting the experiments.

- Experiments were not repeated in a sufficient manner and they did not last long enough.

Due to the above-mentioned factors, the exact conclusion could not be drawn out of the experiments. However, some results dependable enough to support the reported facts in the "Report on Evaluation of Promoting Measures for Prevention of Public Nuisances and for Safety of Motored Vehicles" issued by the Society of Automobile Engineers of Japan were obtained. Namely:

- With the increased collision velocity of the vehicle, higher values for repelled distance and acceleration were obtained and this result is in agreement with the fact that the increased velocity intensified pronounced severity of injuries.
- For the conventional vehicles as well as the vehicles with special shape bumper, the collision acceleration values of the head turned out appreciably high, especially, the collision acceleration values of the head against the road surface were found pronouncedly high, showing elevated death rates and severe injury rates.
- Not a single dummy was run over by the experimental vehicle employed in the present experiments which had a collision against the dummy, provided that the brake of the particular vehicle was operated.
In the above-mentioned report, only few cases were given.
- It was confirmed that existence of the side guard (side guards) on the heavy truck exercised an intensive influence on the behavior of the dummy.

Pedestrian versus Passenger Car

- By means of modifying the vehicle front shape in a special manner, change of the behavior of the dummy itself can be expected.
Especially, it is possible to expel the dummy sideways that had a collision with the vehicle on its extreme end on both sides.
- With the bumper provided with a lowered point of collision against the lower part of the leg, the collision acceleration value against the lower part of the leg can be reduced.

- The injury alleviating measures of modifying the front bumper into an energy-absorbing type revealed a significant effect on the collision inflicted upon the lower part of the leg in the ranges of lower velocities.
- The injury alleviating measures of modifying the bonnet construction into an energy-absorbing type was found to have no effect.
- Regarding the above measures, no appreciable difference of the head collision acceleration value against the road was found in comparison with the conventional vehicles.
- Regarding the head collision acceleration value, its value changes in accordance with the postures of the dummy involved at the moment of collision against the vehicle and of its landing on the road surface.
For example, in the case of collision against the vehicle, when a hand contacts first with the bonnet and then, the head makes a collision, the percussion values happen sometime to be lower than in the case when the head makes a direct collision against the vehicle.
- The injury alleviating measures of modifying the bumper into an energy-absorbing type turns out more effectively when this particular measure is combined with the measures of modifying the front end shape of the vehicle involved.
However, the way to expel the dummy sideways is incorporated with various problems when a vehicle is (or vehicles are) running parallel with the vehicle against which the dummy had a collision is taken into consideration.

Effects of Side Guard (for heavy trucks)

- The side guard has an effect of expelling a man in the outward direction, reducing pronouncedly the probability of inflicting severe injury, even to lethal extremity, on the victim by running over it with a rear wheel.
Further, in the case of injuries inflicted on the pedestrian caused by a collision, more difficult

problems are involved if the shock occurred when he fell on the road surface than if the shock occurred when he had the collision against the vehicle body.

On the other hand, a slight difference of the contact points of the dummy with the vehicle, reveals considerable effects on the behaviors of the dummy.

- The mounting position of the side guard should be located in line with the extreme outside position of the tire for obtaining better results.

Dummies

The dummies employed in this present experiment could not be of the kind that reproduce with complete fidelity such behaviors that are assumed by the pedestrian who is crossing the motor vehicle traffic road.

For example, for maintaining the upright standing posture of the dummy, a support rod was necessary; an individual dummy had its own rigidity of the joint and elastic property of its surface material.

As far as the child dummy is concerned, this particular dummy, because of the limited time given to the manufacture of this dummy, did not represent such precision and ingenuity as was originally conceived.

Accordingly, development of more sophisticated experimental dummies is a matter of the greatest importance.

Acceleration Value

It is not possible to clarify how the measurements of the acceleration value taken on the accelerometer reflect upon the grade of medical injuries and accordingly, it is beyond the scope of this experiment to evaluate the grade of injuries.

It is a matter of dire necessity to further the scientific research work on the relationship between the physical measurements and human reflection by means of the closest cooperation of medical experts and engineers.

Experiments On Passenger Car And Pedestrian Dummy Collision

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Japan Automobile Research Institute, Inc.

INTRODUCTION

Of the total number of deaths and injuries in motor vehicle traffic accidents in Japan, those of pedestrians account for 35%, bringing into focus the importance which pedestrian motor vehicle traffic accidents have come to assume of late. Owing to many factors involving this problem, its technical analysis has lagged behind the measures being taken for occupant protection.

With a view to solving this problem as much as possible, we have spent several years on it, conducting a series of experiments. In this experimentation, which we are going to reveal here today, medium-sized motor vehicles and dummy pedestrian representing a whole human figure are brought into collision, and the relationships between the vehicle front form and the impact location of the dummy and their corresponding impact location of the vehicle, and the value of the acceleration which occurs in the collision, etc., are preponderantly studied so as to obtain data in the interest of developing a pedestrian-oriented safety vehicle.

EXPERIMENTAL METHOD

The method of experiments is outlined in Figure 1. For the sake of simpler collision conditions for the experimentation, a dummy is standing facing the vehicle center and it is allowed to be hit. Dummy used is a 50 percentile Japanese adult male, which is held suspended under the condition that the greater part of his own weight is placed on the ground, and whose magnetic retainer is released as soon as the vehicle comes within 0.5m-1m from the dummy, and makes it free, then allows it to collide with the central part of the vehicle front. Experimental vehicles — weighing 1,000 kg or less and formed as illustrated in Figure 2 — come into collision, with their brake applied at a 0.5g constant level. Impact accelerometers built into its head, chest, pelvis and lower leg, and its trajectory traced by high-speed photography.

EXPERIMENTAL RESULTS

The impact sustained by a pedestrian can be divided into two stages — the primary impact which occurs when the pedestrian comes into collision with any possible part of the vehicle and the secondary impact which the pedestrian suffers as he or she is brought into collision with the road surface immediately after the primary impact. The following description will be made on the basis of this bipartite division (see Figure 3).

Primary Collision

The correspondences between the location of the dummy and the location of the motor vehicle at the time of a primary collision as obtained in the present experimentation are given in Figure 4. The bonnet has high energy absorption property, and the collision of any area of the dummy body with the bonnet produces low acceleration. For example, at the time of face to face collision, the chest is bound to crush against the bonnet but a peak-G value at this time is 60g or less even if the collision occurs at 40 km/h (see Figure 5). If this collision takes place against the ventilator region or the windshield glass or other rigid areas of the vehicle, high acceleration is produced. This is by no means lower than the acceleration which results from a secondary collision (see Figure 6). The head comes into collision not only with the bonnet but occasionally with the ventilator region which results in high peak-G readings. Especially on smaller vehicle experiments, the head impact is almost there.

Therefore, measures against primary collisions are best taken by reducing these rigid regions to a minimum and preventing collision with them as much as possible.

Considering from vehicle front form, the one whose nose region is low (1) has less impact on the human pelvis at the time of a crush, and in relation to impact on the head, too, is more advantageous owing to the head hitting the bonnet in collisions at up to 20 km/h. At 30 km/h or more, however, the head comes in violent contact with the ventilator region resulting in a great impact. Experimental vehicle (2) has a generally low and small bonnet, which results in

SCHEMATIC SKETCH OF THE METHOD OF EXPERIMENT

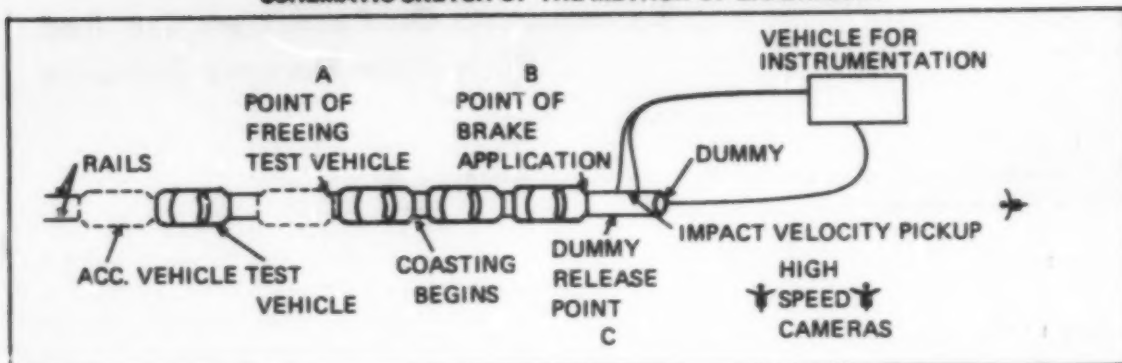


FIGURE 1

FRONTAL FORM OF TEST VEHICLES

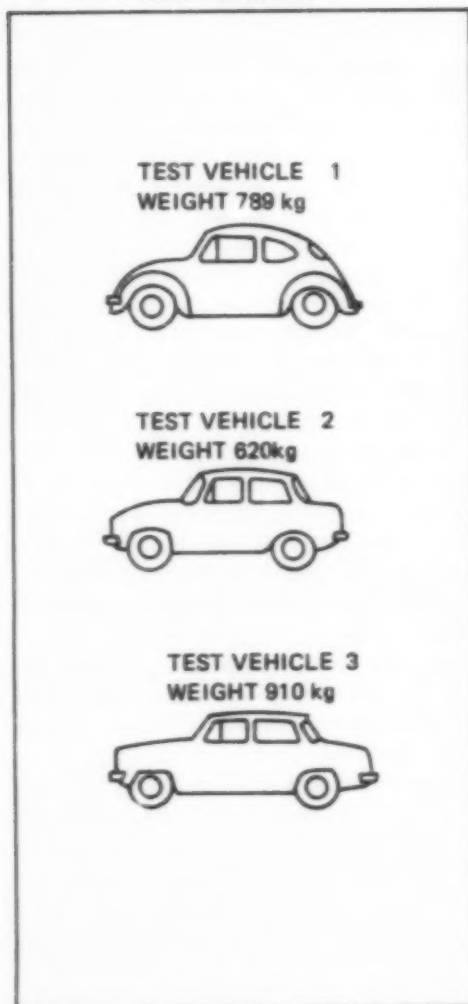


FIGURE 2

SEQUENTIAL SKETCH OF THE DUMMY BEHAVIOUR TEST VEHICLE 1 (IMPACT VEL. 41.0 km/h)

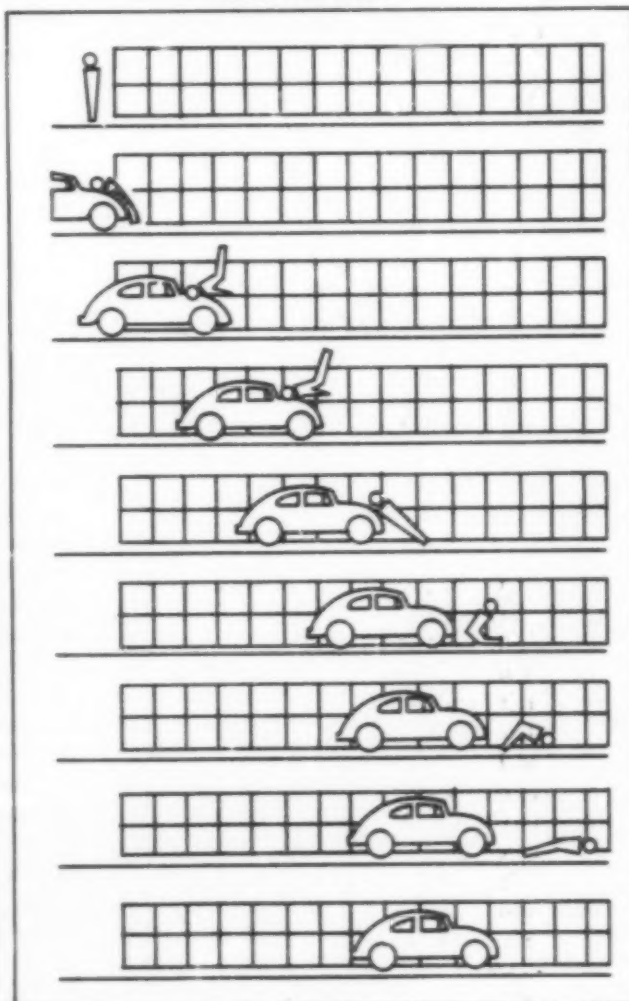


FIGURE 3

the dummy head directly hitting the windshield glass and sustaining a great impact, but otherwise is advantageous in shape because of its least impact on the pelvis and little upward kick or fling.

Experimental vehicle (3) is disadvantageous on account of its far larger impact on the pelvis than other models, but since the position of the head collision with the vehicle differs little with collision velocity, it is advantageously shaped to enable the establishment of effective countermeasures.

Secondary Collision

The secondary collision occurs about 700 - 1200 msec after the primary collision. At this time, the trajectory of the dummy differs according to the impact velocity, the vehicle front form, the mode of brake application and other factors. In this report, forms of falling or dropping are classified into the following four patterns on the basis of the experimental results.

- Pattern A:** A prone fall in which the leg lands first, with the pelvis, the chest and the head suffering blows.
- Pattern B:** If the upward kick and the throw-out or hurl are more extensive than in the case of Pattern A, a fall often occurs parallel with the road surface.
- Pattern C:** Should the upward kick be larger than in the case of Pattern B, a fall occasionally takes place head over heels, with the head landing first.
- Pattern D:** Frequently, a fall is had supinely in a posture the reverse of Pattern A, B, and C.

The results of the producing vehicles experiments reveal that at an impact velocity at 20 km/h or less, Pattern A results, and at 20 - 30 km/h, Pattern B is the case, while at 30 km/h or more, the results indicate a trajectory of Pattern C.

Pattern D occurs irrespective of velocities. At 40 km/h, all four Patterns are observed. In this case, the form of a fall on the road surface is identical but the form differs in which the dummy is thrown out or hurled. This we call the Pattern at High Speeds. In other words, the four Patterns of trajectory of a fall are divided into Patterns at Low Speeds and Patterns at High Speeds at the borderline of about 25 km/h. (Pattern C, however, occurs at speeds higher than 30 km/h and is therefore hard to differentiate.) Figure 7 animates the outline of the patterns of fall.

Secondary collision being a violent contact with a hard road surface, the dummy is likely to sustain large surface pressure at the time of collision, thus making injuries by fall fatal. The acceleration wave form at this time exhibits a sharp rise with short duration time (see Figures 8 and 9). In primary collisions, the collision locations of the dummy and those of the motor vehicle almost correspond, but in secondary collision, their respective locations of collision differ with each experiment owing to differences in the form of falling.

The most important problem in decreasing injuries is how to decrease the cases of injury on the head. Here consideration is given to the head injuries and forms of falling. In Figure 10, the axis of abscissa represents the maximum acceleration at secondary collision divided by impact velocity as secondary collision coefficient and the axis of ordinate represents frequencies of each pattern. As is clear from this figure, Pattern A is the most advantageous in form of falling. Accordingly, for the sake of cutting injury incidence in secondary collision, it is best to devise a set of conditions in which the form of motor vehicle and the mode of energy absorption, etc., combine to orient the forms of falling to Pattern A.

Figure 11 illustrates the patterns of falling with respect to each experimental vehicle. Experimental vehicles (1) and (2) assume Pattern A in all of their experiments at 30 km/h or less. With experimental vehicle (3), Patterns B and D are noted. This shows that at 30 km/h or less, vehicles (1) and (2) with the nose portion held low, are more advantageous. To further study this point, experimental vehicle (3) had its front region elongated, its nose region lowered to remodel it to the form of like experimental vehicle (1), and is made into experimental vehicle (3L). As a result, the remodeled vehicle exhibits Pattern A in all of three experiments on it, again demonstrating the preference of low-nosed type (1) of vehicles. At around 40 km/h, there are no significant clear-cut differences between experimental vehicles, and yet Pattern A is occasionally noticed—a fact indicative of the feasibility of making forms of falling safer in pattern.

CONCLUSIONS

Of the impacts sustained by pedestrians, the primary impact and secondary impact can effectively be considered in relation to the collision regions of the vehicle and to the patterns of falling, respectively, in studying vehicle safety factors. For both the

CORRESPONDING IMPACT AREAS BETWEEN DUMMY AND VEHICLE

	Head	Pelvis	Chest	Lower Leg
Bumper				○ 30 - 350g
Nose			○ 100 - 170g	
Bonnet	○ 100 - 220 g	○ 25 - 75g	○	
Ventilator	○ 220 - 500g			
Wind Shield	○ 200 - 400g			

FIGURE 4

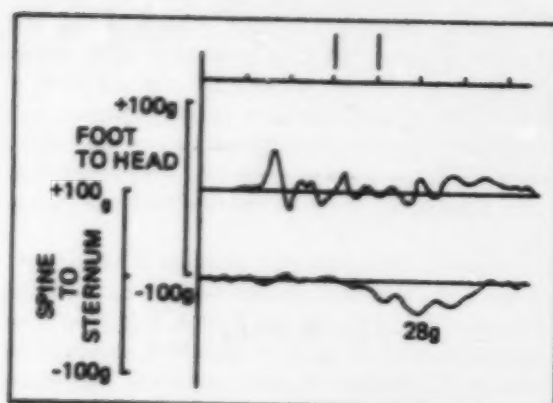


FIGURE 5

**CHEST ACC. ON PRIMARY IMPACT
TEST VEHICLE 1 IMPACT VEL. 41.3km/h**

**HEAD ACC. ON PRIMARY IMPACT TEST
VEHICLE 2 IMPACT VEL. 38.1km/h**

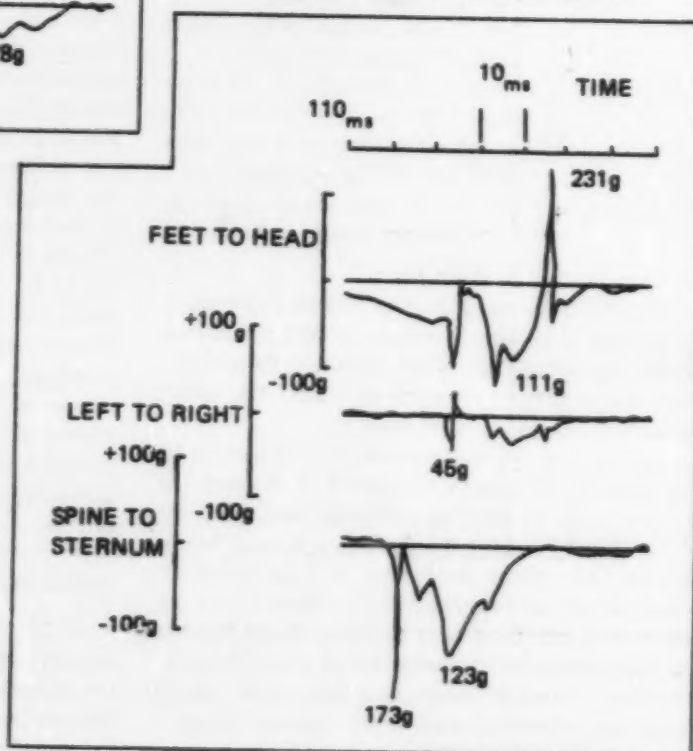


FIGURE 6

SEQUENTIAL SKETCH OF EACH PATTERN

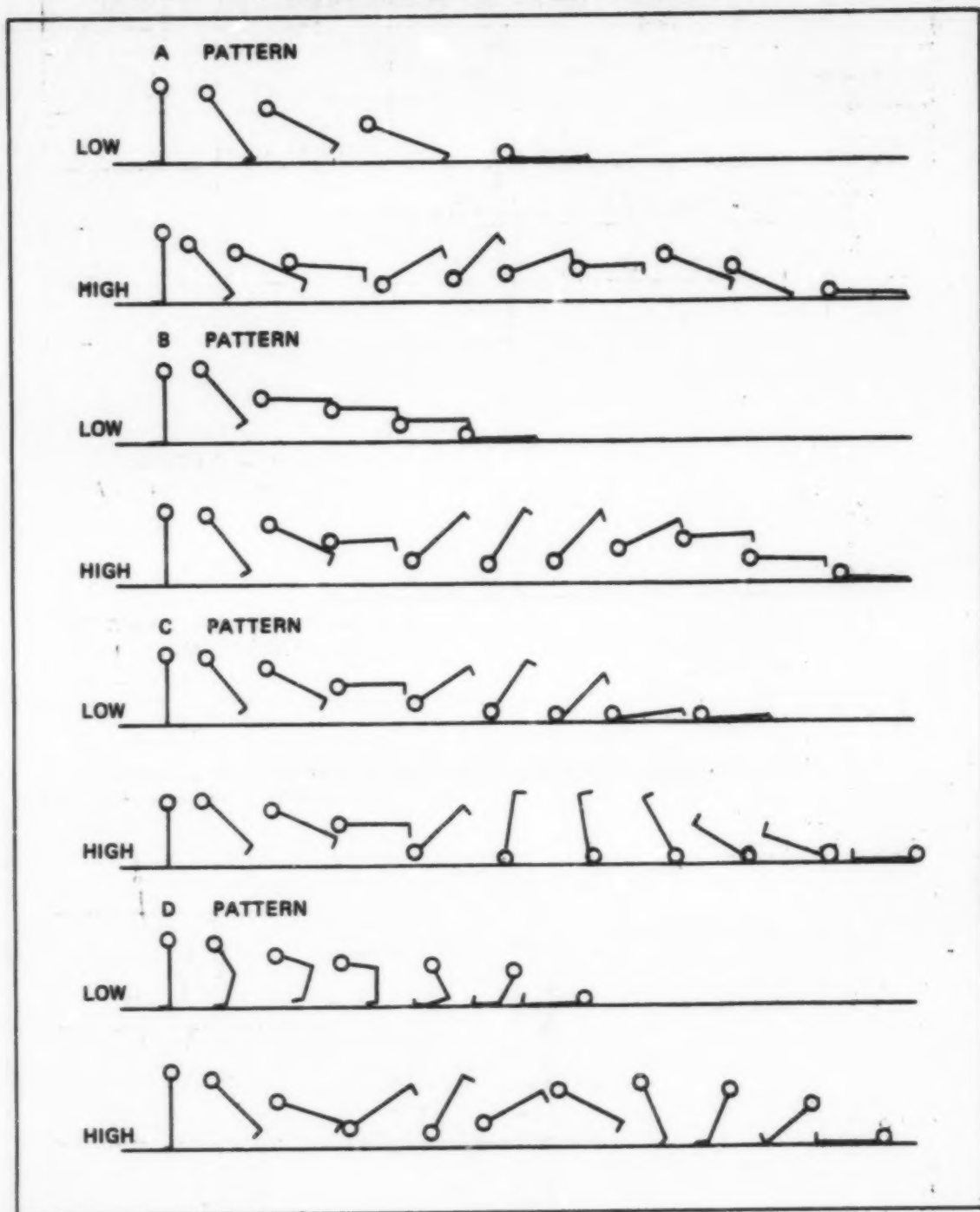


FIGURE 7

HEAD ACC. ON SECONDARY IMPACT TEST VEHICLE 3 (IMPACT VEL. 13.7 km/h)

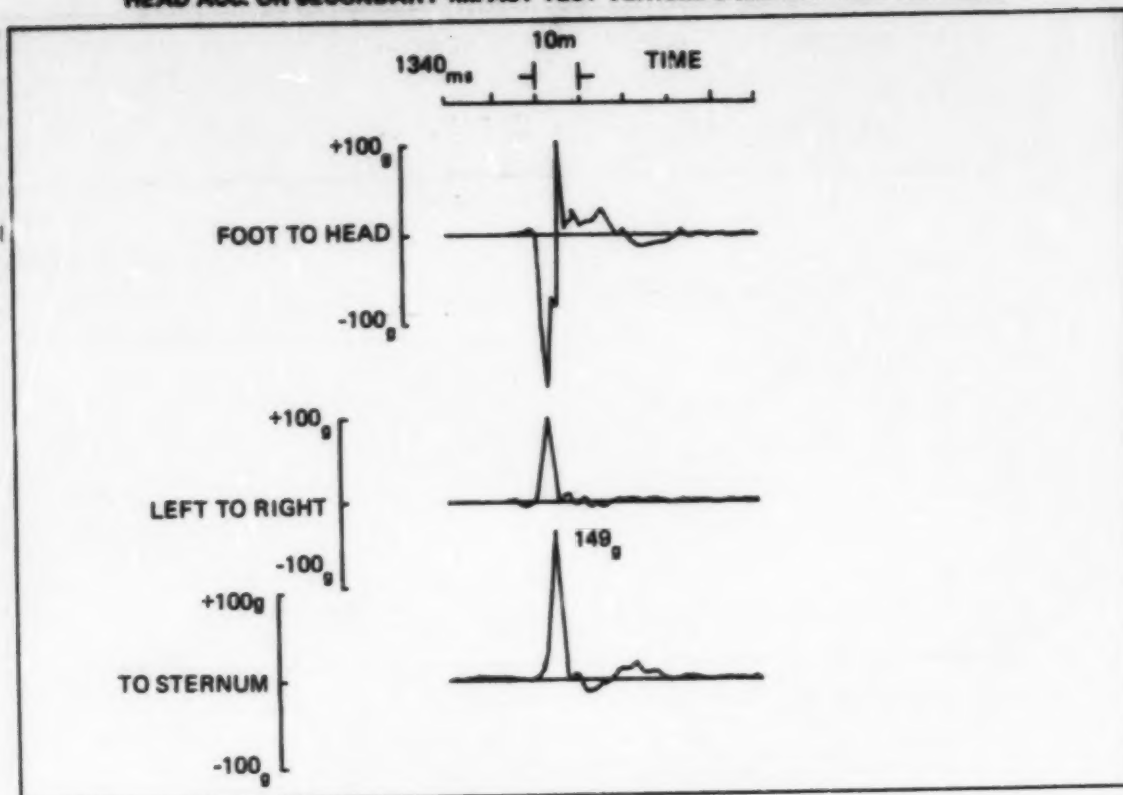


FIGURE 8

HEAD ACC. ON SECONDARY IMPACT TEST VEHICLE 2 (IMPACT VEL. 36.1 km/h)

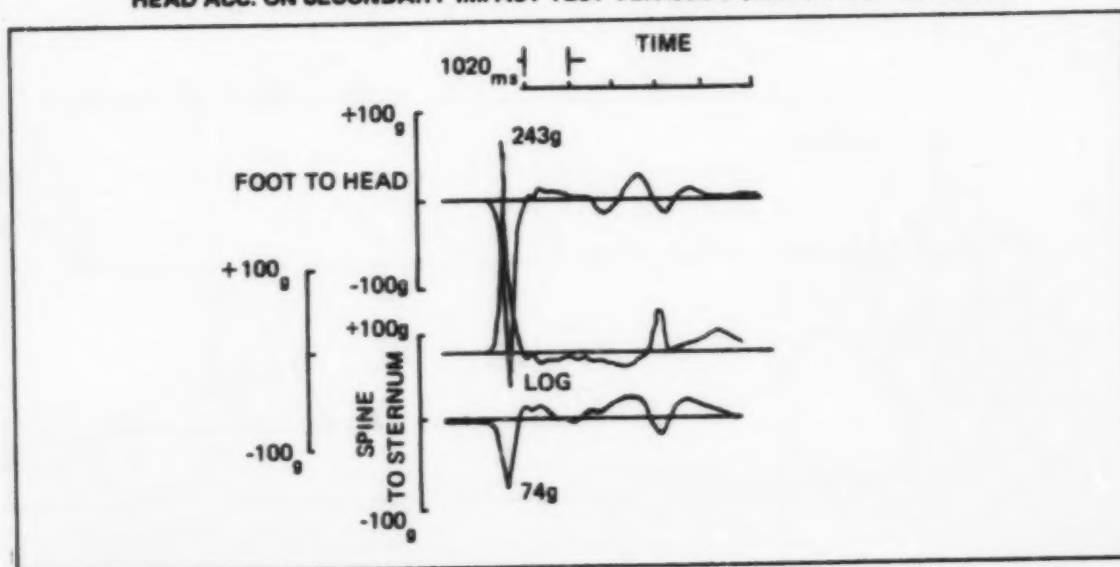


FIGURE 9

DISTRIBUTION SPECTRA BY MAX. G/IMPACT VOL.

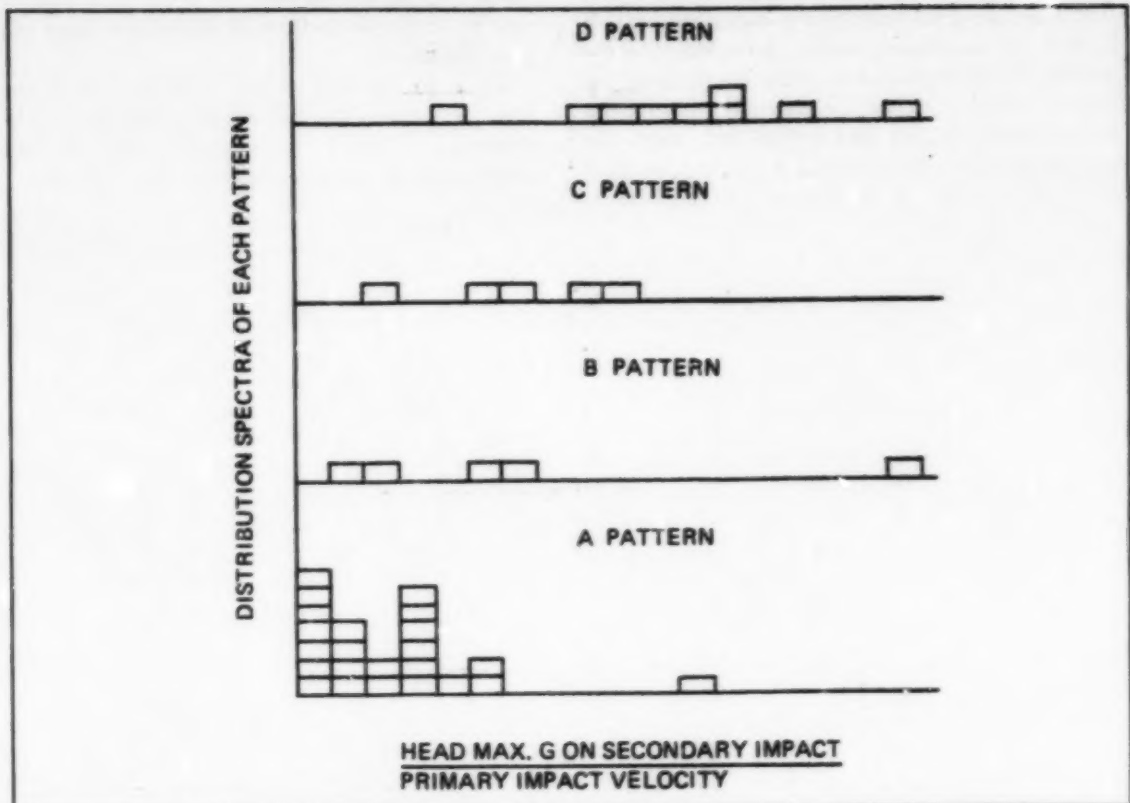


FIGURE 10

PATTERN DISTRIBUTION OF TEST VEHICLES

		D	AA B	B	A A A D	C A	BD C C
TEST VEHICLE 3							
TEST VEHICLE 3L				A A		A	
TEST VEHICLE 2			A A		D C D		A
TEST VEHICLE 2L	A		A A	B		AD D D	A
TEST VEHICLE 1		A	A A	D	A A	D A	CD DD
IMPACT VEL.	10 km/h	20	30	40			

FIGURE 11

primary and secondary impacts, the experimental vehicle (1) with lowly-placed nose is doubtlessly far safer than the other types. For an impact velocity, 25 km/h or so is considered to be a safety limit for the present. Other experimental results are obtained but they are as yet unconvincing, due to the complicated factors which dummy and vehicle have alike. The present series of experiments have hardly covered all of the factors that include vehicular parts dimensions,

relative positions, rigidity, impact velocity, degree of brake application and their influences plus dummy rigidity, joint characteristic, its collision attitude and their influences.

These factors shall be duly studied in our future round of experiments, the results of which shall be reviewed in detail to provide data for the development of pedestrian-oriented safety vehicles.

Pedestrian Safety Research

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ABSTRACT

Automobile impacts with pedestrians continue to account for approximately 10,000 fatalities and 150,000 injuries on the nation's roadways annually. This remains an area of the total highway fatality and injury spectrum which is virtually unaddressed by present safety standards.

A review of past pedestrian impact research consisting of statistical analyses of accident data, experimental impacts utilizing vehicles and pedestrian surrogates, and development of various analytical pedestrian simulators reveals the areas and direction needed for additional research in pedestrian impact protection area.

The National Highway Traffic Safety Administration's pedestrian impact protection program is discussed and considered in relation to both the objectives of pedestrian injury mitigation and compatibility with the design considerations of the crashworthiness programs.

THE PEDESTRIAN PROBLEM

Automobile impacts with pedestrians account for a significant portion of the total number of motor-vehicle related fatalities and injuries occurring on our nation's highways yearly. Last year the National Safety Council (1)* reported that 10,600 pedestrian deaths and 150,000 injuries occurred within the United States in 1971. This represents 21.6 percent of all highway fatalities and 2.6 percent of all highway injuries. Yet to date, no substantial measures have been incorporated into the design of vehicles to effect a mitigation of pedestrian injuries and fatalities. In fact, present design trends, motivated by the objectives of achieving a more crashworthy structure, may well present a harsher environment in which the pedestrian must survive.

Detailed analysis of pedestrian accidents in the U.S. by Calspan (2), and by Mackay and deFonka (3) in England both indicate that the pedestrian

*Numbers refer to references at back of paper.

receives his injuries from two main sources: the vehicle and the road. Of these two sources, injuries resulting from vehicular contacts occur somewhat more frequently than injuries resulting from ground contacts, and the vehicular contacts produce more severe injuries than do ground contacts. The major injury producing components of the vehicle are the hood edge, the bumper, the forward hood, and the grill (listed in descending order of severity). The predominant injury to an adult pedestrian from vehicular contact is to the leg, followed by the lower torso, the head, arms, and the upper torso. Considering vehicular contact with children, head injuries become predominant, followed by legs, lower torso, arms, upper torso, and neck injuries. The predominance of head injuries among child pedestrians is attributable to the fact that the head is exposed to direct contact with the front of the vehicle while this is not the case with the adult. Severe ground related injuries to the adult and the child pedestrian are to the head, followed by the legs, arms, and the torso.

It is also evident from the pedestrian accident statistics that 77% of pedestrian impacts involve the front of the car and that the majority of impacts occur at velocities less than 20 mph. Of the injuries occurring in frontal impacts below 20 mph, only 7% can be categorized in the serious-fatal range while 82% of the frontal impact injuries at greater than 20 mph are serious-fatal. Furthermore, when considering all serious-fatal accidents, 89% occur at velocities below 30 mph.

Impacts with the side of vehicles account for approximately 20% of all pedestrian impacts, and these impacts result in somewhat less serious injuries than front impact accidents. That is, while 15% of the front impacts were serious-fatal, only 5% of the side impacts were in this severity range.

It is evident from the above data that the pedestrian impact problem is indeed a severe one and that a significant effort should be made to reduce both the fatalities and injuries associated with this phenomenon. The obvious solution would be to entirely separate the pedestrian and the motor-vehicle; an enormous task with a considerable economic burden and a large inherent time delay.

A less ambitious preventative approach to the pedestrian problem would be to strictly control where and how pedestrians and vehicles interact. This is done by markings, signs, lights, and various other devices which not only make both the pedestrian and the vehicle operator aware of each other's proximity but also limit their movement relative to each other.

However, to insure an adequate reduction of pedestrian injuries and fatalities, an alternative approach, one that assumes that a significant number of the pedestrian-vehicle impacts remain inevitable and that the impact effects to pedestrians must be controlled and minimized, should also be pursued.

But before this approach and any of its supporting research efforts are discussed, it is appropriate to consider past pedestrian research which will lend more insight into the solution of the total problem.

PREVIOUS RESEARCH

One of the earlier significant works was conducted by Severy and Brink (4) of the Institute of Transportation and Traffic Engineering at UCLA. They conducted an experimental impact program utilizing dummies and actual vehicles. A total of twelve experiments was run attempting to correlate such parameters as impact speeds, size of car, pedestrian size, impact position, braking or not, and structural characteristics of cars. Some of the conclusions reached from these experimental runs were: (a) At speeds of 10 mph, impact of the car tends to be of a severity comparable with the subsequent pavement impact. For speeds of 20 mph and higher, the initial car impact is usually two to three times more severe than subsequent impacts with the pavement, (b) head accelerations resulting from vehicle impact for an adult increase exponentially with increases in impact speeds, while small children's head accelerations increase linearly with speed, (c) compared with the pedestrian weight, the weight of the striking car, whether small or large, is not a significant injury factor, but the pedestrian-height-to-car-profile relationship determines, in a large measure, the struck pedestrian's movement and injury exposure, and (d) sheetmetal provides an excellent energy absorber.

Cornell Aeronautical Laboratories (2) conducted an investigation of the pedestrian accident problem under sponsorship of the NHTSA. This investigation became a three-part research effort consisting of investigations of pedestrian and cyclist accidents, development and application of a computer

simulation to the dynamics of pedestrian impacts, and an exploratory experimental study of impact loadings and structural deformations. The accident investigation phase obtained data defining 265 pedestrian-vehicle impacts in the metropolitan areas of Buffalo, New York and Toronto, Canada. Several of the significant results of this phase were incorporated in the previous discussion on accident statistics. The pedestrian-vehicle impact model, a two-dimensional, three mass, five degree-of-freedom simulation, confirmed the analysis of both Severy et al. and the accident data, i.e., the severity of injury increases exponentially with the impact speed and above 20 mph the majority of impacts are serious or fatal. The model also gave indications that both the vehicle profile and its structural properties play an important role in vehicle-related and ground-related injuries and that vehicle braking or the lack of it contributed significantly to the ultimate pedestrian kinematics. The third phase of the investigation, the impacting of actual vehicle components with various head forms, confirmed the greater hazard to head injury from the hood edge when compared with the top of the hood.

Another NHTSA sponsored pedestrian research effort was conducted by the Texas Transportation Institute of Texas A&M University (5). This effort is now in its final stages of documentation. It consists of three major areas of investigation. The first being the development of an injury index based on the average strain-energy density in the various body segments and an empirical relationship which assesses the combinatorial effect of several simultaneous injuries of various levels of severity. The second area attempted to assess the relative significance of the approximately 50 parameters observed in the accident investigation statistics of the previous CAL contract and develop a functional relationship between these and the level of injury. This resulted in a relationship containing a linear dependence on pedestrian-vehicle height ratio and a non-linear dependence on the initial impact velocity.

The third area of investigation is an experimental verification of the ability of the three-dimensional TTI pedestrian model to simulate actual tests of a dummy dropped on a vertical vehicle buck. Preliminary results verify the model's ability to simulate some pedestrian-vehicle impacts but a great deal of attention must be focused on determining the pedestrian's (dummy's) initial conditions and the method with which contact forces are analytically generated.

Cook and Nagel (6) conducted an investigation of impact injury to the knee joint. The experimental series included impacts to both bovine and fresh cadaver legs. They identified peak impact force as the dynamic variable that correlated most strongly with the degree of trauma produced but insufficient data prevented formulation of a comprehensive injury tolerance criteria.

A combination of experimental and analytical investigations of pedestrian-vehicle impacts was conducted by the Japan Automobile Manufacturers Association (7). This consisted of a series of 26 experiments with velocity of impact ranging from 10 km/hr through 40 km/hr and was one of the first experimental efforts which attempted to assess the effects of extreme vehicle modifications on pedestrian kinetics and kinematics. One such modification was the addition of a large wedge-shaped front end to the vehicle. This introduced a significant reduction in the leg accelerations of the pedestrian at initial contact, probably due in part to energy absorbing characteristics of the structure and in part to lower point of contact of the structure with the leg. But this latter characteristic became extremely detrimental at higher impact speeds because the structure caused the dummy to acquire large rotational velocities and impact its head more severely at a stiffer area near the windshield.

Other additional investigative efforts [McLean, et al. (8), and Hall et al. (9)] continue to affirm the same basic general facts about pedestrian-vehicle impacts that the previous facts have. That is:

- pedestrian impacts constitute a significant portion of the fatalities and injuries attributable to motor-vehicle accidents
- the majority of these impacts involve the front end of vehicles
- the predominant injuries (legs, lower abdomen, head) are attributable to impacts with either the vehicle or the road but with vehicular impacts, in general, being somewhat more severe
- the proportion of pedestrian fatalities increases sharply as the speed of collision rises, and
- the shape and compliance characteristics of the vehicles' surface not only determine the trauma due to vehicular impact but contribute directly to the pedestrian's subsequent kinematics and resulting trauma from impact with the road surface.

PRESENT STATUS

The research efforts described above contribute to the general understanding of the pedestrian problem yet definitions of specific remedies for the mitigation of the problem are still unobtainable. This inability to promulgate rational and effective performance standards for pedestrian impact protection is the result of, or more specifically, the lack of the following essential elements:

- The lack of a comprehensive, active, data base representative of the total pedestrian problem, and the techniques capable of analyzing this data base to locate the major problem concentrations and identify the levels of their significant defining parameters. (This data base could be used later for evaluating the effectiveness of any resulting standards or detect new problems if they should arise.)
- The lack of quantitative injury measures and tolerances for assessing not only the seriousness of actual pedestrian injuries for input into the data base but the severity of experimental impacts when using pedestrian surrogates.
- The lack of an accurate, economical method of characterizing and replicating real-world pedestrian accidents.
- The lack of a systematic method of minimizing the overall hazard to the pedestrian by determining the optimum practical combination of the many controllable parameters which define the pedestrian-vehicle impact.

FUTURE RESEARCH

Cognizant of these technical deficiencies, the NHTSA has formulated a comprehensive research plan which will address all the significant areas needed to effect a solution to the pedestrian impact problem. The emphasis of these planned efforts will concentrate in both the analytical and experimental areas.

In the analytical area, the modeling of the pedestrian in the impact environment will be done at two levels: gross-motion simulation and detailed structural modeling. The gross-motion simulation will determine the kinetics and resulting kinematics of a pedestrian-vehicle impact. It will allow an investigation of the relationships between the many parameters which define and control the outcome of an impact. A simulation of this type will necessarily sacrifice some of the details of the impact event in

order to accommodate the larger scope of the investigation economically.

Therefore, to understand the impact phenomenon more fully, detailed structural analysis techniques are also being developed and applied to areas which will greatly benefit the pedestrian program. This includes finite element models of both the head and neck and the thorax. These models will contribute to the understanding of the prevalent injury mechanisms occurring during impact and to the development of realistic injury tolerance criteria. The finite element techniques will also be utilized in characterizing the vehicular structures that the pedestrian has contact with, i.e., the bumper, fender, hood. Additional efforts are being directed toward the development of general analytical techniques capable of determining the contact forces and their distribution between two impacting deformable structures. This will then allow merging of the human and vehicular finite element models to obtain a complete description of the vehicular response and the resulting human response and injury. This capability will also be extremely useful as a design tool in evaluating prospective vehicular materials and configurations.

The experimental areas will not only provide material parameters and validation data for both the gross-motion simulators and the finite element representations but supply the necessary data to formulate injury criteria, conduct tests to evaluate experimental modifications, demonstrate production feasible designs, and develop compliance procedures and devices.

Several research contracts for fiscal year 1973 address specific areas of pedestrian safety research. One contract, entitled "Body-Vehicle Interaction," will attempt to quantify the forces, accelerations, velocities, and resulting injuries to the legs and lower abdomen of pedestrians being struck by automobiles. The research emphasis is on understanding the injury mechanisms and developing realistic injury tolerances for these body areas. To insure this, the use of unembalmed cadavers, placed in an experimental configuration which accurately duplicates the loading conditions of one of the several predominant pedestrian impact modes, is required. In addition, the program will investigate the material properties of candidate energy absorbing bumper coverings for their injury mitigating potential and the effectiveness of the most promising will be experimentally evaluated.

Another research contract entitled, "Contact Loads-Experimental Study," will attempt both the

experimental determination and analytical characterization of contact forces during a pedestrian-vehicle impact. Initially, validation of the Calspan 3-Dimensional Crash Victim Simulator (10) in a pedestrian configuration will be conducted. Since the entire motion and any resultant measure of injury calculated by this mathematical simulation is a direct result of the contact force algorithms used it is imperative they receive the closest scrutiny and be completely validated to assure the accuracy of future simulations. To guarantee this, the validation phase will include not only a correlation with the dummy drop test previously conducted at the Texas Transportation Institute, but will also attempt correlation with an additional eight experimental pedestrian-vehicle impacts using extensively instrumented dummies and fresh cadavers. If the present contact force algorithms prove inadequate, they will be revised or alternative formulation will be constructed.

The contract also calls for a restructuring of the Calspan model so that when sufficient experimental kinematical data is inputted (i.e., accelerations, velocities, and displacements) the kinetic contact forces, of which the motion was a result, can be calculated as functions of time. This could eventually provide a good compliance technique because it would eliminate the necessity of incorporating load cells in any vehicle being tested.

A third contractual effort, entitled, "Pedestrian Model Parametric Studies," addresses the problem of how to best utilize large analytical simulators when attempting to optimize a problem such as the pedestrian one. Since the complexities of these models require a considerable effort in constructing their input modules and each run results in a cost of several hundred dollars, it is essential that any optimization technique utilized must be capable of characterizing the desired objective function in the n-parameter space as quickly as possible and searching this resulting hyper-surface to determine the optimum point with a minimum number of iterations. The contractual effort will initially conduct an extensive review of existing optimization techniques. They will be ranked by their ability and efficiency to perform optimization and parametric sensitivity studies on complex non-linear models and objective functions. Then, if necessary, additional theoretical development will be pursued to develop a unified optimization capable of handling problems as complex as the pedestrian one.

Once this is achieved, the technique will be applied, utilizing the best available analytical pedestrian simulator and the most accurate injury assessing criteria, to determine the optimum combination of the many vehicle parameters which will minimize the overall injury producing hazard of vehicles to pedestrians.

Future NHTSA efforts will then attempt to validate experimentally the efficacy of the design changes determined to be most beneficial to pedestrian injury mitigation, and develop demonstrations of production feasible modifications of these specifications to present vehicles. Strong effective coordination will exist between the pedestrian safety research programs and the occupant crash survivability programs to not only insure that the resulting structural specifications of one program are not contradictory with the other but that they combine to give an optimum combination of specifications that mitigate the hazards of both crash environments.

To ensure effective application of the resulting pedestrian protection standards when promulgated, parallel efforts will develop both test equipment and procedures which will determine if any given vehicle design can comply with them.

CONCLUSIONS

The severity and magnitude of the national pedestrian-vehicle impact problem has been recognized and a significant effort has been undertaken by the NHTSA to effect a reduction of both pedestrian injuries and fatalities. This effort not only continues the accident avoidance approach now underway but specifically addresses itself to the problem of mitigating the effects of the actual pedestrian impact.

Deficiencies in the past efforts of pedestrian impact research that have prevented the establishment of effective vehicle standards have been identified and specifically addressed by new research efforts. These immediate efforts coupled with appropriate follow-on efforts will determine the feasibility of and hopefully result in the ability to

design and specify general structural and geometric characteristics of vehicle fronts which will mitigate the pedestrian's extreme vulnerability to injury during impact.

REFERENCES

1. Accident Facts 1972, National Safety Council, Chicago, Illinois 60611.
2. "Research in Impact Protection for Pedestrians and Cyclists," Final Report, National Highway Traffic Safety Administration, Contract Number FH-11-6955, May 1971.
3. Mackay, G.M. and C.P. de Fonseca, "Some Aspects of Traffic Injury in Urban Road Accidents," *Proc. of Eleventh Stapp Car Crash Con't.*, October, 1967.
4. Severy, D. and H. Brink, "Auto-Pedestrian Collision Experiments," Automotive Engineering Conference, Detroit, Mich; SAE-66080, January 10-14, 1966.
5. "Vehicle Exteriors and Pedestrian Injury Prevention," Final Report, National Highway Traffic Safety Adm., Contract No. DOT-HS-065-1-217, August, 1972.
6. Cook, F.W. and D.A. Nagel; "Combined Medical-Engineering Study of Injury and Damage to the Knee Joint in Impact," Final Report: National Highway Safety Bureau, Contract No. FH-11-6877, June 1969.
7. "Experiments on Behaviors of a Pedestrian in a Collision with a Motor Vehicle," Summarized Report, Japan Automobile Manufacturers Assn., Inc.; August 1968.
8. McLean, A.J. "Car Shape and Pedestrian Injury," National Road Safety Symposium, Canberra; March 1972.
9. Hall, R.R. and A.J. Fisher, "Some Factors Affecting the Trauma of Pedestrians Involved in Road Accidents," *The Medical Journal of Australia*, 1972, 1:313 (February 12).
10. "A Three-Dimensional Computer Simulation of a Motor Vehicle Crash Victim," Final Report, National Highway Traffic Safety Adm., Contract No. FH-11-7592, July, 1971.